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SHEET-METAL WORKER

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CROSBY LOCKWOOD & SON

LONDON

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THE

SHEET-METAL WORKER'S GUIDE

THE

SHEET-METAL WORKER'S GUIDE

A PRACTICAL HANDBOOK

FOR

TINSMITHS, COPPERSMITHS, ZINCWORKERS,

ETC.

COMPRISING

NUMEROUS GEOMETRICAL DIAGRAMS AND WORKING PATTERNS, WITH DESCRIPTIVE TEXT

BY W. J. E. CRANE

AUTHOR OF "THE SMITHY AND FORGE"

SECOND EDITION, REVISED AND CORRECTED

LONDON

CROSBY LOCKWOOD AND SON

7, STATIONERS' HALL COURT, LUDGATE HILL

1888

LONDON:
PRINTED BY J. S. VIRTUE AND CO., LIMITED,
CITY ROAD.

PREFACE.

This little volume is intended to present to the trades concerned in working sheet-metal a collection of the most useful patterns in the several branches. It therefore includes those adapted for tin-plate, zinc, and copper; also, for the first time, as far as the Author is aware, in any English book, some for galvanized iron cornice work. Lead has been excepted, it having been dealt with by many other authors in books upon Plumbing.

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SHEET-METAL WORKER'S GUIDE.

CHAPTER I.

SHEET-METAL WORKING.

This book is mainly one of patterns, and these are necessarily divided between the various branches dealing with sheet metal—viz. tin, zinc, copper, and sheet iron. Having premised that this is principally a pattern-book, let us give a cursory glance at the processes of sheet-metal work before proceeding to the patterns.

First of all, when the form of the pattern is marked out on the sheet metal, the next business is to cut it out: this is generally effected with a large pair of shears, either screwed up in the vice or with their shank dropped into a hole in the bench, and worked by hand (Fig. 1). In some instances, however, the cold chisel and hammer are employed, the work being

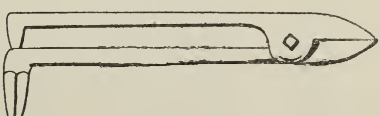


Fig. 1.

either laid on the anvil direct or on a cutting-

plate; in others, being screwed up in the jaws of the vice and cut off by the hammer and chisel, the latter being kept in contact with the upper surface of the vice-jaw as a guide. Sometimes, the thick plates employed for boilers are screwed up in very long vices with a screw at each end and cut off by the chisel. There are also slitting-plates in large works.

The hammers (Fig. 2) are alike at both ends as a rule, sometimes with large faces either flat or convex. The faces or panes are always kept very bright, in order that they may impart some of their polish to the work, a process which is termed "planishing." Wooden hammers or mallets are often used to prevent stretching the sheet metal. The anvils are of very varied shapes, and generally placed in a hole in the work-bench. The smaller ones are usually called "stakes," and go down to half an inch square. Fig. 3 is the "hatchet-stake," and is much used for turning over edges, &c.; this varies from 2 inches to 10 inches wide. Fig. 4 is a "taper-stake," also much used. Fig. 5 is the "creasing tool," which is used for making small beads, tubes, &c. Fig. 6 is the "seam set," used for closing the seams prepared at the hatchet-stake. Fig. 7 is the "Holliper" or "Oliver": it consists

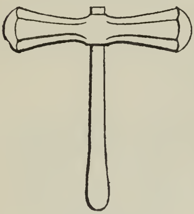


Fig. 2.

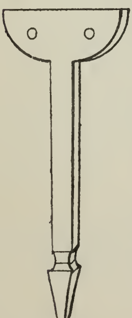


Fig. 3.

of two jointed arms, in which various kinds of top and bottom tools, swages, &c,. can be fixed, and the metal being placed between the dies, and the top forcibly struck with a hammer, the piece of tin, &c., is at once stamped out exactly to the contour of the dies.

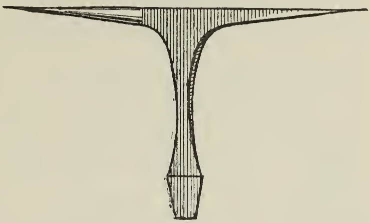


Fig. 4.

The sides of the vessel (which is a shallow tray) represented in Fig. 8, if the metal be thin, would

Fig. 5.

Fig. 6.

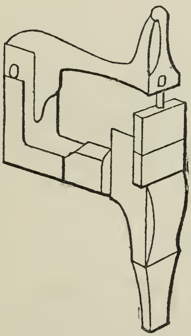


Fig. 7.

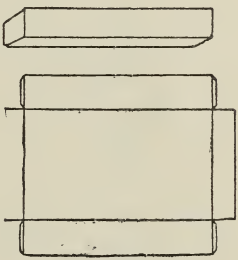


Fig. 8.

be bent to the required angles by laying the metal horizontally on the hatchet-stake, with each angle line exactly over the edge of the same, and blows would be given with the mallet, or with the hammer for more accurate angles, so as to indent the metal with the edge of the stake; it would then be bent down by the fingers, unless

the edges were very narrow, as for the seam, when the mallet would alone be used. Thicker metal is more commonly bent over the square edge of the anvil, a square set-up hammer being held upon its upper surface; and sometimes the work is pinched fast in the vice, and is bent over with the blows of a flat-ended punch or set, applied close to the angle, and then hammered down square with the hammer. Very stout metal is seldom bent, but cut and the angles riveted.

Thin metal is bent to curves by holding one edge and placing the other edge on the beak-iron, around which the sheet is (Figs. 9 and 10)

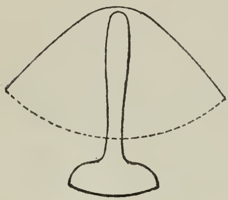


Fig. 9.

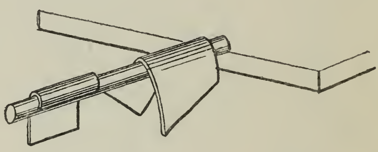


Fig. 10.

curled by the mallet. The crease (Fig. 5) is frequently used for making seams or edging. A strip of sheet metal is laid in the appropriate groove, and an iron wire is driven down upon it by the mallet. The wire, of course, bends the strips when driven down; the edges are then folded down upon the wire by the mallet, and it is then finished by a punch or top tool (Fig. 11) matching the groove in the crease.

JOINTS.

Let us now glance at the various methods of making joints at angles of sheet metal, as at Fig. 12. A and B are for the thinnest metals, such as tin, which requires a film of soft solder on one or the other side. Sheet lead is similarly joined, and both are usually soldered from within.

C and D are the *butt* and *mitre* joints, used for thicker metals, with hard solders. Sometimes D is dovetailed together, the edges being filed to correspond coarsely; sometimes they are partly riveted before being soldered from within. These joints are very weak when united with soft solder.

Fig. 11.

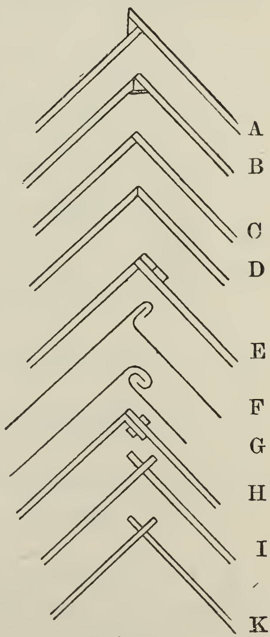


Fig. 12.

E is the *lap* joint, the metal being creased over the hatchet-stake. Tin plate requires an external layer of solder; spelter solder runs through the crack and need not project.

F is folded by means of the hatchet-stake, the two are then hammered together, but require a film of solder to prevent their sliding asunder.

G is the *folded angle* joint, used for fireproof deed-boxes and other strong work, in which solder would be inadmissible. It is common in tin and copper work, but less so in iron and zinc, which do not bend so readily.

H is a *riveted* joint, which is very commonly used in strong iron plate and copper work, as in boilers, &c. Generally a rivet is inserted at each end, then the other holes are punched through the two thicknesses on a block of lead. The head of the rivet is put within, the metal is flattened around it, by placing the small hole of a riveting set over the pin of the rivet, and giving a blow; the rivet is then clenched, and is finished to circular form by the concave hollow in the riveting set.

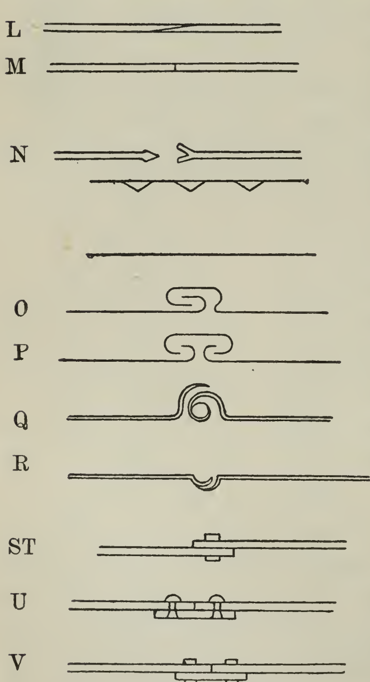


Fig. 13.

In I K one plate is punched with a long mortise, the other being formed into tenons, which are inserted and riveted. K, however, has tenons with

transverse keys, which can be taken out and the plate released.

Let us now see to the straight joints.

L (Fig. 13) is the lap joint, employed with solder for tin plates, sheet lead, &c., and for tubes bent of these materials.

M is the butt joint, used for plates and small tubes of the various metals. When united by hard solders or brazed, such joints are moderately strong, but with soft solders the joints are very weak, from the limited superficies of the adhering surface.

N is the *cramp* joint. The edges are thinned by the hammer, the one is left plain, the other is notched obliquely with shears for one-eighth of an inch deep; each alternate cramp is bent up, the other down, for the insertion of the plain edge; they are then hammered together and brazed; after which they may be made nearly flat by the hammer, and quite so by the file. The cramp joint is used for thin work requiring *strength*, and amongst numerous others, for the parts of musical instruments. Sometimes the lap joint (L) is feather-edged. This improves it, but it is still inferior to the cramp joint in strength.

O is the lap joint, without solder, for tin, copper, iron, &c. It is set down flat with a seam set, and is used for smoke-pipes and numerous works not required to be steam and water tight.

P is used for zinc works and others. It saves the double bend of the preceding. It is sometimes called the "patent strip overlap."

Q is the roll joint, used for lead roofs.

R is a hollow crease, used till recently for vessels and chambers for making sulphuric acid. The metal is scraped perfectly clean, filled with lead heated nearly to redness, and the whole united by burning with an iron also heated to redness. Solder which contained tin would be attacked by the acid. Now superseded by autogenous soldering.

S T, joints united by screw-bolts or rivets, for iron and copper boilers, &c.

U, united with rivets, in ordinary manner of uniting the plates of marine boilers and other work requiring to be flush externally.

V is a similar case, used of late years for constructing the largest iron steam-ships, &c. The ribs of the vessel are made of **T** iron, varying from about 4 inches to 8 inches wide, which is bent to the curves by the employment of very large surface-plates cast full of holes, upon which the wood model of the rib is laid down, and a chalk mark is made around its edge. Dogs or pins are wedged at short intervals in all these holes, which intersect the course; the rib, heated to redness in a reverberating furnace, is wedged fast at one end and bent around the pins by sets and sledge hammers, and as it yields to the curve each pin is secured by wedges until the whole is completed.

Zinc.

Our illustrations of this metal principally refer to junctions of external rainwater gutters or troughs.

In London and large towns the gutters and pipes are usually of cast iron, sometimes of galvanized iron; but in very many country places zinc has followed lead in this capacity, and proves a convenient and safe substitute.

Gutters are very easily formed of zinc. The slip of the desired width being cut off the roll with shears or knife, is gently hammered to the correct curvature over a mould of wood made to

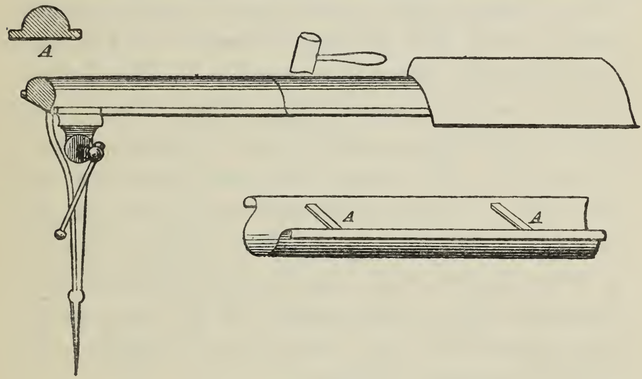


Fig. 14.

order by the carpenter, something like in section A, Fig. 14, which is screwed up in one or a couple of vices, or otherwise fixed firmly on the shop-board. When this is done, the trough is turned right way up, and the "stays," which are formed of a small piece of zinc, rolled up round into a kind of close tube, are soldered across from side to side of the top at intervals (A A, Fig. 14), to hold the trough together and brace it. Of course, the angles at which the guttering joins at any in-

ternal or external angles of the roof will be cut to shape before the zinc is curved, and it is in this case that plans of proper cutting out are useful. It must be remembered that zinc is a less pliable metal than lead or copper, or even than tinned iron, and very springy. This last qualification renders it difficult to get zinc to take and retain a new shape when worked cold. But if it be heated over the fire to nearly boiling-point (212° Fahr.) there will be no more trouble on this score. It is not so easy to solder as tin, and resin is rather uncertain with it. The hydrochloric acid (commercially called "spirits of salts") acts better, and so does "Baker's soldering fluid." The copper bit, well tinned, is the tool used. There are several newly invented gas blow-pipes or soldering-jets (one by Mr. Fletcher, of Warrington, very good) which act well with moderate care. The surface of the zinc at the joints should be clean and scraped bright. Do not use too much solder.

Galvanized Iron.

This is comparatively a recent material. Of course, ordinary thin sheet-iron has been in use almost from time immemorial, but its range was limited from its excessive tendency to rust, and it was only for such purposes as stove-pipes, &c., that it was applicable. The discovery of coating it with zinc (*i.e.* "galvanizing" it) has largely added to its utility. With us it is principally used for rain-water guttering, but in the United

States there is a large industry concerned in the production of galvanized iron cornices for architectural purposes. In place of using cornices and string-courses of stone in the fronts of brick houses, as we do, the American prefers those of sheet iron made in long lengths, and fixed to wooden blocks let into the brickwork, or to suitable rod-iron supports similarly fixed. As it is not unlikely that the fashion may spread here, where it would probably be of great use to small and country builders, we deem it fit to notice the practice here, and append a few specimens of joints. Some of these cornices, when containing many members of mouldings, especially if they are circular in plan, need much skill. In general principle the metal is bent over the hatchet-stake with mallet or hammer, much as in making zinc guttering, assisting with swages where necessary. The following observations on "Circular Work" are by Mr. C. Vaile, Superintendent of the Cornice Works at Richmond, Ia., U.S.A.

"In making up circular mouldings, it is necessary to have the material sufficiently heavy to bear shrinking and stretching without breaking or becoming brittle. The best plan for bringing mouldings to the required shape is in the following manner: Take a piece of hard wood (oak) 4 inches by 4 inches and 12 inches long, make a profile of work intended, and on one end of this piece make a die of the desired shape; to this must be fitted a plunger, allowing the thickness

of iron to intervene. The die is shown in the following figures: Fig. 15 is the top; Fig. 16 is the sectional view of the plunger and die for a half-round mould. Fig. 15 is to be made in the same circle as work. Figs. 17 and 18 are the same, of a different moulding. Figs. 16 or 18 is to be placed in an oak block, as Fig. 19. The right-hand portion should be of sufficient length to answer for a seat to the operator. Fig. 20 is a

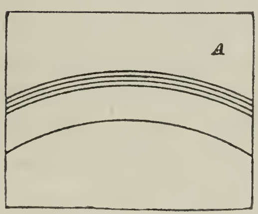


Fig. 15.

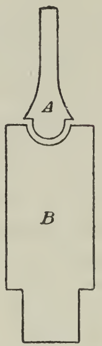


Fig. 16.

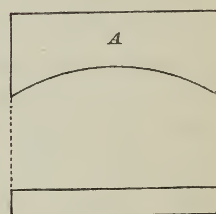


Fig. 17.

mallet about 12 inches long. To make these dies, imagine the cap to be stamped from one piece, and get out the die and plunger accordingly. The tools required will be a saw, brace, and ½-inch bit, a straight chisel, two or three sizes of gouges, a straight rasp, and a rasp curved at one end. When the iron is cut to the required pattern, it is raised in these dies, shifting the mould to and fro each time it is forced into the die with a blow on the plunger from the mallet,

until it is brought to the required shape. A little practice will soon demonstrate the utility of this method, and also its superiority over the hammering process.

"When work is to be put together, never place two raw edges together. On one of the members turn $\frac{1}{8}$ of an inch edge, and lap the member on this and soak the solder in well, so as to firmly

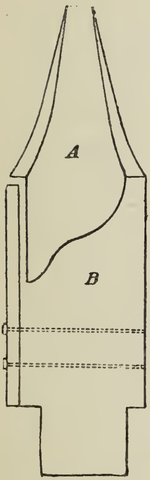


Fig. 18.

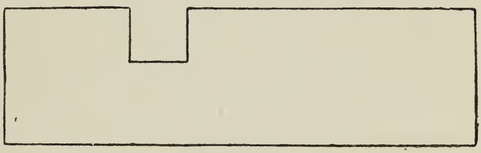


Fig. 19.

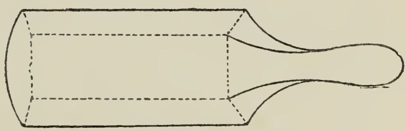


Fig. 20.

unite the pieces, and on the top strip that is to be built in the wall turn a $\frac{1}{2}$-inch edge, to stiffen and answer the purpose of straps to hold the cap in position. An edge of the same kind should also be turned on bottom strip, to extend over the frame; and if the cap is to have a drop or corbel, let the inside of the drop or corbel extend back

past the frame at least one inch, to secure the corbel to the frame, and the other side of corbel have a $\frac{1}{2}$-inch edge to fit against the wall.

"Should the work be for a building already up, the strip should have an edge sufficient to nail through into mortar joints. Good judgment is required in putting up work of this character, to make it a success."

CHAPTER II.

SOLDERING.

Soldering is the process of uniting the edges or surfaces of similar or dissimilar metals and alloys by partial fusion. In general, alloys or solders of various and greater degrees of fusibility than the metals to be joined or placed between them, and the solder, when fused, unites the three parts into a solid mass; less frequently the surfaces, or edges, are simply melted together with an additional portion of the same metal.

The solders are alloys of various kinds, and are broadly distinguished as *hard-solders* and *soft-solders*. The former only fuse at the red heat, and are consequently suitable alone to metals and alloys that will endure that temperature; the soft-solders melt at very low degrees of temperature, and may be used for nearly all the metals.

The forms of soldered joints in the sheet metal have been already given at pages 5 and 6.

The following table exhibits most of the facts necessary to be known, relating to the solders and their use. It contains the composition of the various solders, the fluxes suitable for each, and

the manner of applying the heat. This is abridged from Holtzapffel's "Mechanical Manipulations."

"Soldering may be divided generally into two branches, viz. 'hard-soldering' and 'soft-soldering.' The first process may be used with all metals less fusible than the solders, the modes of treatment being nearly similar. The hard-solders used are generally spelter solders, the flux usually borax, A, and the mode of heating the naked fire, the muffle, or furnace, and the blow-pipe (*a*, *b*, *g*). Laminated gold is used for soldering platinum, copper for iron, gold for gold alloys; spelter solders, granulated, for iron, copper, brass, gun-metal, German silver, &c. Soft-soldering is applicable to most of the metals. The methods pursued are very various. The soft-solder mostly used is composed of two parts of tin and one part of lead; sometimes, from economical motives, much more lead is employed, and $1\frac{1}{2}$ of tin to 1 of lead is the most fusible of the group, unless bismuth is used. The fluxes B to G, and the modes of heating *a* to *i*, are all used with the soft-solders. In the following examples the metals to be soldered are placed first, then the number of the alloy to be used as solder, next the capital letter signifying the flux to be employed, and lastly the italic letter which indicates the mode by which the heat should be applied.

"Iron, cast-iron, and steel, 8, B D; if thick heated by *a*, *b*, or *c*, and also by *g*.

"Tinned iron, 8, C, D, *f*.

"Silver and gold are soldered with pure tin or with 8, E, *a*, *g*, or *h*.

"Copper and many of its alloys, namely, brass, gilding metal, gun-metal, &c., 8, B, C, D, when thick heated by *a*, *b*, *c*, *e*, or *g*, and when thin by *f* or *g*.

"Speculum metal, 8, B, D, C; the sand-bath is perhaps the best mode to apply heat, which should be done cautiously.

"Zinc, 8, *c*, *f*.

"Lead and lead pipes, or ordinary plumber's work, 4 to 8, F, *d* or *e*.

"Lead and tin pipes, 8, D and G mixed, *g* and also *f*.

"Britannia metal, 8, C, D, *g*.

"Pewters—the solders must vary in fusibility according to the fusibility of the metal; generally G and *i* are used, sometimes also G and *g* or *f*.

"Burning together is sometimes adopted for brass and iron, and lead is united by pouring on red-hot lead, with the aid of a red-hot iron.

Alloys and their Melting Heats.

No.								Fahr.
1.	1	tin	25	lead				558
2.	1	—	10	—				541
3.	1	—	5	—				511
4.	1	—	3	—				482
5.	1	—	2	—				441
6.	1	—	1	—				370
7.	1½	—	1	—				334
8.	2	—	1	—				340
9.	3	—	1	—				356
10.	4	—	1	—				365
11.	5	—	1	—				378
12.	6	—	1	—				381
13.	4	lead	1	tin	1	bismuth		320
14.	3	—	3	—	1	—		310

No.									Fahr.
15.	..	2	lead	2	tin	1	bismuth	......	292
16.	..	1	—	1	—	1	—	......	254
17.	..	2	—	1	—	2	—	......	236
18.	..	3	—	5	—	8	—	......	202

NOTE.—By the addition of 3 parts of mercury to No. 8 it melts at 122 deg. Fahr., and may be used for anatomical injections and for stopping teeth.

FLUXES.

A Borax.
B Sal-ammoniac or mur. of ammonia.
C Muriate or chloride of zinc.
D Common resin.
E Venice turpentine.
F Tallow.
G Gallipoli oil or common sweet oil.

MODES OF APPLYING HEAT.

a Naked fire.
b Hollow furnace or muffle.
c Immersion in molten solder.
d Molten solder or metal poured on.
e Heated iron not tinned.
f Heated copper tool tinned.
g Blow-pipe flame.
h Flame alone, generally alcohol.
i Stream of heated air."

—From the *Mechanics' Manual.*

For the soft-solders, the soldering-iron is the most general agent for applying the heat; for the hard-solder, forge or other fires, or the blow-pipe, are generally adopted. *Brazing* (used with sheet brass and sheet copper) may be defined as soldering with fusible brass, and hence as a form of hard-soldering.

It is necessary that all soft-soldered joints should be very clean and quite free from any metallic oxide. It is therefore the general practice to scrape the adjacent parts for everything except clean tin-plate.

The copper soldering-bit (usually misnamed

the "soldering-*iron*") is shown at A, Fig 21. It consists of a small piece of solid copper riveted between the forked end of a split iron rod, the

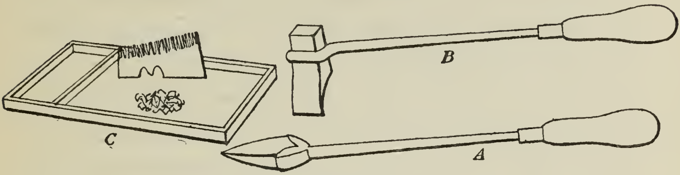


Fig. 21.

whole being provided with a wooden handle. Sometimes the copper-bit is made of the form of B, and fixed as there shown. These are usually termed "hatchet-bits" from their shape. All works in tinned and sheet iron, and many of those in copper and brass are soldered with the copper-bit, which in general suffices to convey all the heat required to melt the more fusible solders now employed.

If the copper-bit has not been previously tinned, it is heated in a small charcoal stove, or otherwise, to a dull red, and hastily filed to a clean metallic surface; it is then rubbed immediately, first upon a lump of sal-ammoniac, and next upon a copper or tin plate upon which a few drops of solder have been placed. This will completely coat the tool; it is then wiped clean with a piece of tow, and is ready for use.

The copper "bit," or end, must always, as we have said, be "tinned," or covered with tin, before using. This will always need to be done.

Here is another plan: File it bright with a fine file and give it a pointed end, not too sharp, and then put it into your charcoal or coke fire. Get a soft red brick and scoop out a hole about as big as a cherry in its top surface. When the bit is not quite red hot, hold the bar of solder in your left hand over the hole in the brick, and touch it with the hot bit in such sort that the metal drops in the cavity; drop also a pinch of powdered resin on it. Now rub the bit round and round in the brick until it gets cool, and by that time, if the operation has been properly performed, it will be coated with solder.

In soldering coarse works, when their edges have been brought together they are slightly strewed with powdered resin, contained for convenience in the side compartment of the box, Fig. 21. The soldering-iron is held in the right hand, the cake of solder in the other, and these being brought into contact, at short intervals, as the hand passes down the seam, a few drops of solder are let fall on the joint here and there. The end of the bit is then applied to the joint and passed along it, so that it fuses the solder and distributes it along all parts of the joint, so as to fill it entirely up. Only a portion of the joints, say about 6 inches or 8 inches, is thus dealt with at a time.

It is very usual to keep two soldering-bits in use, so that while one is in hand the other may be heating in the stove. It is impossible to make satisfactory work unless the tool be kept at a

sufficient heat. It should not, however, be raised to too great a heat, or the tinning will be burned off and will need to be replaced.

It is often found convenient to fix the cake of solder upright in the flat box that contains the flux. In this position a few drops can be taken from it, on the heated bit. (Fig. 21, *c*.)

Dexterous workmen will often make a good joint by passing the soldering-iron once only along the edge or fold of the metal, and leave a very fine and regular line of solder. To ensure this, the bit must be kept very thin and sharp at the edge, and the flux must be the muriate of zinc or killed hydrochloric acid (spirits of salts, mentioned at page 10); the joints being moistened with this by means of a skewer, previously to the application of the iron.

Copper works are more commonly fluxed with powdered sal-ammoniac, and so is likewise sheet-iron, although some mix powdered resin and sal-ammoniac; others moisten the edges of the work with a saturated solution of sal-ammoniac, using a piece of cane, the end of which is split up into a kind of brush, and subsequently apply resin. Each plan has its advocates, and each appears to work well in accustomed hands.

Besides the usual copper-bit, the plumber employs a large heavy bulbous iron in soldering. This is especially used for joints in lead pipe, which requires to be very sound. These are generally extremely clumsy in appearance, as by the aid of the hot iron and a piece of tick held in

the left hand the plumber manages to plaster a great bulbous patch of solder round the point of junction, which they term a "wiped" joint.

The blow-pipe (mouth) is used to some degree in soft-soldering, principally by the gasfitter, who is generally remarkably expert in making joints in his composition pipes therewith. These are not made like the plumber's, by inserting one end of the pipe in the other and the plastering a bulb of solder around the place, but by cutting off the pipes with a fine saw and filing them up square and smooth to butt together into a mitre or a T-joint. These joints have frequently to be made in very awkward and confined situations amongst joists under floors, &c., and are generally effected by applying the heat from one side only, by holding a small bundle of dried ignited rushes there, and forcing the flame thus obtained upon the joints with a blow-pipe. They generally use a rich tin solder, and employ a flux of oil and resin in equal parts.

The pewterers generally use the hot-air blast, by means of a peculiar cast-iron apparatus employed only in their trade. They use fusible solder containing bismuth, and for flux a common green olive oil termed Gallipoli oil.

For hard-soldering an intense fire-heat is required, similar to that obtained in the smith's forge. In fact, the ordinary blacksmith's forge is frequently used for brazing, although the process is injurious to the fuel as concerns its normal purpose.

The brazier's hearth, for extensive works, is

generally a plate of iron about 4 feet by 3 feet, supported on four legs at its corners, and with a central opening about 2 feet by 1 foot and 6 inches deep for the fuel. The blast is generally supplied by a fan, and the tuyere-irons have large apertures.

Fresh coal should never be used, but charcoal, or, failing that, coke or cinders. Lard in the fire is very prejudicial.

In all cases of hard-soldering or brazing the meeting edges are to be scraped or filed clean (especially when the heat used will not reach the *red* degree). The work in copper, iron, brass, &c., having been prepared and the joints retained in position by binding with iron wire when needful, the granulated spelter and powdered borax are mixed in a cup with a very little water, and spread along the joints by a slip of sheet metal or a small spoon.

The work is now placed above the clear fire, first at a small distance to gradually evaporate the moisture and deprive the borax of its water of crystallization. During this process the flux boils up with a frothy look, and sometimes shifts the solder away. The heat is now increased, and when the metal assumes a faint red the borax melts like glass. As the metal gets deeper red the solder fuses also, generally with a slight blue flame if it contains any zinc. Generally at this point the solder "flushes" or disappears in the work. Should it not do so, and appear refractory on the score of running into the joint, the work

may be tapped with the tongs, in order to make it move. Care must, of course, be taken that the heat is not so much raised as to melt the work as well as the solder. If the work be iron, there is, of course, little need of precaution.

If it is iron which you wish to braze, you have to file the meeting surfaces bright; make a little borax into a paste with water, and smear them over with this. Next tie them together with some fine iron wire, just enough to prevent the pieces from coming apart. Then wind them round and round at the place of the joint with several coils of fine brass wire, rubbing them over with the borax paste. This is then laid on the fire and the blast put on. Presently a small blue flame will be seen reflecting over the place. This is a sign that the brass wire is melting and that the heat is dissipating the zinc constituents of the brass, and the brass having melted and run into the joint the job is done.

It is only iron, however, to which you can apply so much heat. For brass and copper you must have a more fusible metal than brass. This solder is called "spelter" (incorrectly), and is composed of copper and zinc in equal parts. Indeed it is a very soft kind of brass, and liquefies at a much lower temperature than would melt copper or ordinary brass. There are two varieties of spelter, hard and soft, both procurable at any metal warehouse.

The borax (borate of soda) can be got at the same place, or at a drysalter's or chemist's. We

have mentioned its quality of swelling up when heated, and that this swelling displaces the solder on the work. In order to obviate this it is not unusual to heat the borax previously, till this considerable swelling up has subsided and the water of crystallization is driven off, when it can be pounded and kept in a stoppered jar.

The blow-pipe is largely used in hard-soldering and brazing, especially for work in the precious metals.

The ordinary blow-pipe is a light conical brass tube, about 10 inches or 12 inches long, from $\frac{1}{2}$ inch to $\frac{1}{4}$ inch in diameter at the end for the mouth, and from $\frac{1}{16}$ inch to $\frac{1}{50}$ inch at the aperture or jet. The small end is bent in a quadrant, that the flame may be immediately under observation. Very usually it is fitted with a small hollow brass ball just below the quadrant, to serve as a receptacle for the condensed vapour from the lungs. This instrument is generally used with a lamp of a wick from $\frac{1}{4}$ inch to 1 inch in diameter and produces a flame of great heat, the object exposed to it being generally placed upon charcoal.

Gas is frequently used in conjunction with the blow-pipe, and this is especially useful for sheet brass, the work being held in place by wire ties if necessary, and either laid upon a flat piece of pumice-stone or held in a pair of pliers. One of the most useful of blow-pipes is that introduced some short time since by Mr. Fletcher, of Museum Street, Warrington, whose effective gas-furnaces

and stoves are so widely known for lavatory and technical work. This blow-pipe has the nozzle coiled around a time or two. By putting this coiled nozzle in the flame with its orifice in the right position relative to the work, a hot blast is obtained in place of a cold one, rendering the brazing or hard-soldering delightfully easy and satisfactory.

CHAPTER III.

GEOMETRY AS APPLIED TO SHEET-METAL WORKING.

The utility of a tolerable knowledge of practical geometry to those engaged in the sheet-metal trades scarcely needs be insisted upon. It is next to impossible to strike difficult patterns by mere rule of thumb, and although in many workshops templates may be found for the great number of ordinary patterns, still, even then, occasions will certainly arise for the construction of others for special work. Besides, in the present days of technical instruction and active competition, no young man who desires to excel in his trade should be content without the best knowledge available about it. If he will take the trouble, however, to acquire a certain amount of geometrical information, he will be prepared for all emergencies. He will be enabled to work from the roughly drawn outline sketches of a customer with the same unfailing certainty as if the job was one which he had executed hundreds of times instead of being, perhaps, quite new to him. And besides the pleasant consciousness of mastery of

his work the artisan will effect a considerable saving in time, material, and temper on many occasions.

The subject appeals to every worker in sheet metal in a greater or less degree. In the manipulation of tin, sheet iron, zinc, copper, lead, and brass it is brought into exercise.

The geometrical process mainly called in by the sheet-metal worker is that known technically as the "development of solids;" in other words, the representation on a plane of the exterior surface of a cylinder, cone, prism, or many-sided figure. But, besides this, the manner in which such solid bodies are cut, and the "sections" thus arising and their intersections, are not less necessary to be studied, as will become apparent as we proceed.

In many cases the sheet-metal worker's pattern or template for a certain job is simply a development of the geometrical form of the article. If it is one (as is usually the case) which requires to be soldered or brazed together, and there are two or three possible ways of cutting the pattern, the operator will select that whereby he may, as far as possible, reduce such joints. Thus, take a hexagonal-sided tin or sheet-iron box shown at A (Fig. 22). For the purpose of the artisan it may be developed into either the pattern shown at B or that at C. The saving of time effected over cutting its sides and bottom into separate pieces is evident.

Let us now, to render our purpose more plain,

detail the process to be pursued in "developing" one of the simplest of the geometrical solids—namely, the cylinder.

When the surface of a cylinder is developed a right-angled parallelogram (all the geometrical

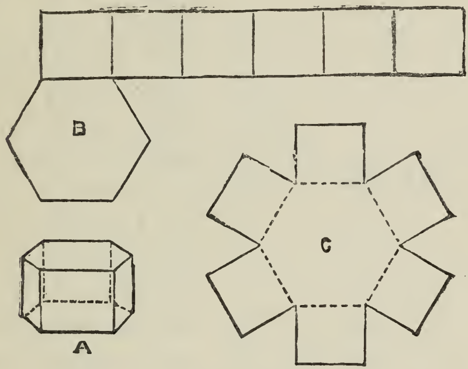


Fig. 22.

terms will be explained as we proceed) is obtained, as at F G H I (Fig. 23), the height of which, G H, is equal to the length of the cylinder, which we will imagine in this case to be equal to the diameter of the cylinder, and the length, F G or H I, is equal to the length of the circumference of the circle, as B E J C. The development of this cylinder will indicate the principle upon which all problems of this kind are based. Let it be required to have the surface of a half-cylinder, as B E C, developed, the height, B G or F D, being equal to the radius, A C. Through A draw the diameter, B C, and extend it indefinitely, as to

D; from E draw parallel to C D a line E F, and from B a line at right angles cutting E F in G. Divide the semi-circumference, B C, into any number of equal parts, as ten in the present case. From B on B D set off these parts to D, from it draw D F at right angles to B D; then F D, B G is the development, or "stretch-out," as it is frequently called, of the semi-cylinder, B E C, and if cut out and wrapped around the said half-cylinder would exactly cover it. If the entire cylinder, as at B E C J, needed to be developed, the "stretch-out" would be twice that of B D, F G.

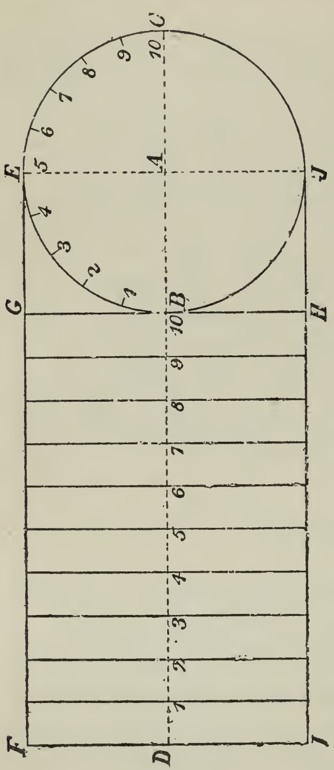
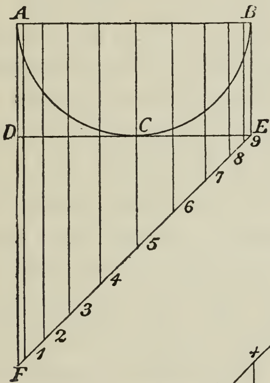


Fig. 23.

Again, let us suppose that it is required by the zinc worker to make a mitre-joint at right angles in a half-round rain-water gutter, or trough, he will proceed geometrically as follows :—Let the semicircle A B C (Fig. 24) represent the sectional outline of the gutter. Draw the line A B, and

draw the lines A F and B E at right angles to A B, also draw the line D E parallel to A B. Make D F equal to A B, and draw the line F E. Divide the semicircle into any number of equal parts (in the present case ten). Draw lines parallel to A F

Fig. 24.



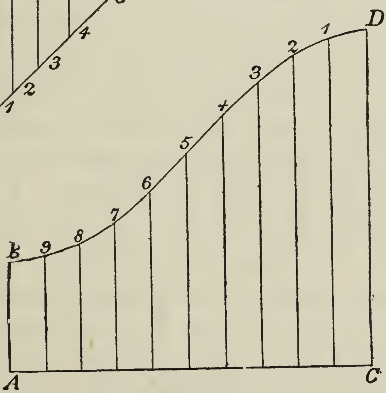


Fig. 25.

through these points in the semicircle, as at 1, 2, 3, 4, &c. Next draw (Fig. 25) A C equal in length to the semicircle, A C B (Fig. 24). Draw the lines A B, C D (Fig. 25) at right angles to A C, and make A B (Fig. 25) equal to B E (Fig. 24),

and C D in the former figure equal to A F in the latter. Set off on the line A C (Fig. 25) the same number of equal distances as the semicircle was divided into. Draw lines parallel to C D (Fig. 25) from each point of division, as 1, 2, 3, 4, &c., and make each of these of equal length to the line correspondingly numbered at Fig. 24. Finally trace the curved line B D (Fig. 25), through the extremities of these lines, and the required pattern of the mitre-joint will be obtained.

As in many other subjects, there is a certain amount of preliminary dry details to be mastered before the subject can be fairly approached. It is just these preliminary, simple, and apparently needless processes that often disgust the learner.

He is apt to think that the special knowledge he desires to gain can be attained by a "hop, skip, and jump" over these—hey, presto!—to the point which appears to him useful and practical.

This is the greatest of mistakes. It is as if a child should hope to learn to read without first painfully acquiring the alphabet. There is no royal road to any knowledge, although care on the part of an instructor may help to smooth the roughness of the way, and this, in the present instance, we shall endeavour carefully to do.

Let us now speak of the tools required, that is, the appliances to enable us to draw the various diagrams.

These are neither numerous nor costly. The following will be sufficient for the present:—A drawing-board of seasoned pine (any board per-

fectly square at its angles will do), a T-square, two set squares, a flat foot-rule with scales, a pair of compasses with moveable leg for pencil, a protractor, a drawing-pen, a pair of dividers, a couple of black-lead pencils (H and H B or F), and a dozen drawing-pins. The entire outfit need cost but a few shillings. We will speak of the use of the instruments as we proceed. Stout cartridge paper (costing about 1d. per sheet) is the best for the purposes of our student.

Before proceeding to teach our readers to construct the various figures most usually required in the trades comprehended by the title of this book, it is requisite that certain terms used in geometry should be explained, as without a good understanding of these our subsequent instructions will not be properly comprehended. We wish our readers to clearly understand that we do not profess in this lesson to teach them the science of geometry, or the art of practical geometry, but merely to illustrate so much of the latter as is applicable to certain special purposes.

It would be infinitely to the advantage of every artisan concerned in these trades to make himself master of the rudiments of geometry. An elementary work on the subject can be got for a shilling, and mastered in a month.

But to proceed with our terms or definitions.

A *point* simply marks position. Theoretically it is said to have no magnitude or size. Practically the smallest point or dot that we can make *has* size, and therefore is really a *surface*,

and not a point. A mathematical point would be the centre of a dot of ink, &c., but for practical purposes the dot itself is spoken of as the point. Sometimes a point is represented by a dot with a small circle around it.

Lines.

A *line* has, theoretically, length or direction only, without breadth. We all know that the finest line which we can produce by a pen or any tool has some breadth. This is not, therefore, the mathematical or ideal line, although we call it a " line " for convenience of practical purposes.

A *straight line* or a *right line* is the shortest distance from one point to another. In drawing heavy lines are called " strong," and light ones " fine." Dotted lines are also used for various purposes. Those formed of different-sized dots (principally employed on plans) are termed "chain lines." At A (Fig. 26) the top line is "strong,"

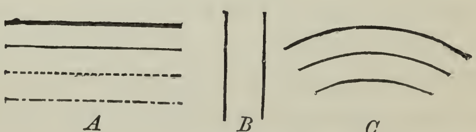


Fig. 26.

the next "fine," the next "dotted," and the lower one "chain."

To *produce* a line signifies to lengthen it at either end.

A *curve* or curved line constantly changes its direction, and is, therefore, nowhere straight (C, Fig. 26). Curves are infinitely variable, and may be *simple* or *compound*. Curved lines may be parallel. When they are parts of different circles struck from the same centre they are termed *concentric* (C, Fig. 26).

Parallels or *parallel lines* are those which are everywhere the same distance apart, and which if *produced* or lengthened for ever, would never meet (see A and B, Fig. 26).

A *horizontal* line is one perfectly level, a *vertical* line is one perfectly upright, having regard to the horizon, as, for example, the line of a plumb-bob. A *perpendicular*, or a *perpendicular line*, is one that is vertical or at right angles to some other line. It is not necessarily *vertical* in

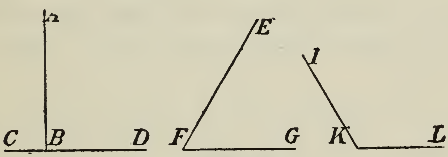


Fig. 27.

the strict sense, but may incline to or even be parallel with the horizon line. (The horizon is the line where sea and sky appear to meet when one looks from the shore.) It is thus clear that while a vertical line is perpendicular to a horizontal one, a horizontal line is perpendicular to a vertical one. The line A B, Fig. 27, is perpendicular to the line C D. An *oblique* line is one neither

vertical nor horizontal, but slanting in regard to some other line, as E F and I K (Fig. 27.)

Angles.

An *angle* (from the Latin *angulus*, "a corner,") is formed by the inclination of two lines until they meet in a point called the *vertex* of the angle. The magnitude or size of an angle does not depend upon the length of the lines forming it, but upon their inclination to each other. Thus, in an angle of 45° (or any other number) the lines may be an inch in length or may be *produced* or lengthened to a foot or a yard without affecting the angle, which still remains one of 45°.

A *right* angle is one formed by one straight line standing upon or being perpendicular to another. Thus the line A B (Fig. 27), being perpendicular to the line C D, both the adjacent angles are right angles and equal. This is the angle of 90°.

An *acute* angle is sharper or less than a right angle, as at E F G (Fig. 27).

An *obtuse* angle is blunter or greater than a right angle, as at I K L (Fig. 27).

Triangles.

Triangles are figures bounded by *three* straight sides, and having in consequence *three* angles. They are also termed trilateral (meaning "three-sided") figures. There are six varieties of

triangles, three named with reference to the length of their sides, and three with regard to the sizes of their angles.

The first three are :—

The *equilateral* triangle, which has its sides equal (A, Fig. 28). The angles are also equal, and each contains 60°.

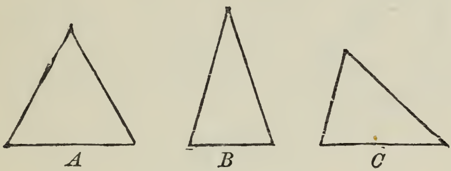


Fig. 28.

The *isosceles* triangle (B, Fig. 28), which has two sides equal. These sides may be longer or shorter than the third side. The unequal side is always termed the *base*, in whatever position the triangle may be represented; the angles at the base are equal to each other.

A *scalene* triangle (C, Fig. 28) has all its sides and angles unequal.

The second division of angles embraces :—

The *right-angled* triangle (left-hand figure of Fig. 29). The side opposite the angle is called the *hypotenuse*, the others being termed the *base* and *perpendicular*, as shown. These terms remain the same in whatever position this triangle is placed.

The *obtuse-angled* triangle (centre figure of Fig. 29) has one obtuse angle

The *acute-angled* triangle (right-hand figure of Fig. 29) is that which has three acute angles.

Although we have specified six kinds of triangles it will become clear that, on a little consideration, one of the three latter kinds must

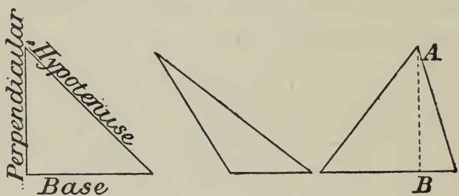


Fig. 29.

also belong to one of the three former classes. In this manner a right-angled triangle must be either an isosceles or a scalene triangle, and an acute-angled triangle may be also an equilateral, isosceles, or scalene triangle.

The highest angle of a triangle is termed its *vertex* (in the plural *vertices*), or *apex* (plural *apices* or *apexes*), or *vertical angle;* the lowest side is called the *base.* With the exception of the isosceles and the right-angled triangle (see page 37), the terms just given are applied to each angle that may be uppermost, or each side that may be lowest when the position of the triangle is altered.

The *altitude* of a triangle is a straight line drawn from the apex to the base, as at A B (Fig. 29).

Any two sides of a triangle, if added together, are greater than the remaining side. It would hence not be possible to form a triangle whose

respective sides were, say, 4 inches, 6 inches, and 10 inches in length.

The three angles of a triangle when added together always equal 180°, or the half of a circle.

Quadrilateral Figures.

Quadrilateral figures are those bounded by four straight sides. They are also called *quadrangles* or four-angled figures. Their united angles always amount to 360°, or four right angles. If the opposite sides of a quadrilateral are parallel to each other it is termed a parallelogram.

The *square* (left-hand figure, Fig. 30) is a parallelogram of four equal sides and four equal

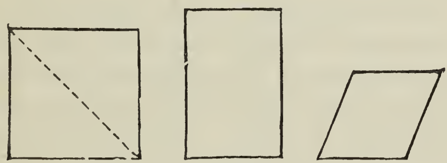


Fig. 30.

angles. A line drawn across a parallelogram from opposite corners is called a *diagonal.*

The *rectangle* or oblong (centre figure, Fig. 30) is a parallelogram, all of whose angles are equal, but only its opposite sides are equal.

The *rhombus* (right-hand figure, Fig. 30) is a parallelogram with four equal sides, having two obtuse angles opposite to each other, and two acute angles opposite to each other.

The *rhomboid* (left-hand figure, Fig. 31)

is a parallelogram having only the two opposite sides equal and also the opposite angles equal.

The *trapezoid* (centre figure, Fig. 31), which has two parallel sides only, but may have some

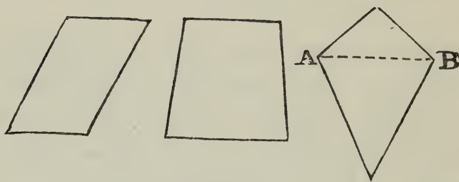


Fig. 31.

of the sides or some of the angles equal to each other or not.

The *trapezium* (right-hand figure, Fig. 31), which has none of its sides parallel, but some of the sides and some of the angles may or may not be equal to each other, or all the sides and the angles may be unequal. A trapezium, one of whose diagonals will divide it into a couple of unequal isosceles triangles (see A B, Fig. 31) is called a *trapezion* or *kite*.

A *polygon* is a rectilinear or straight-lined figure, bounded by more than four straight lines. Polygons are sometimes called multilateral (or "many-sided") figures. They may have any number of sides.

A *regular* polygon has all its sides and angles equal, and can always be so surrounded by a circle, that the circumference thereof shall pass through all the angles of the polygon. The

forms shown at Fig. 32, are regular polygons, that on the left being a pentagon, that in the

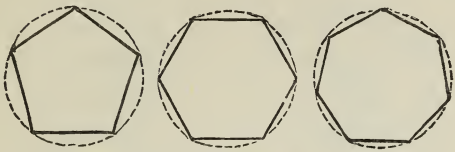


Fig. 32.

centre a hexagon, and that on the right a heptagon.

An *irregular* polygon may have unequal sides and equal angles, or equal sides and unequal angles, or neither may be equal.

Polygons are named according to the number of sides they possess. A polygon may have any number of sides, but for general purposes is seldom found with more than 12 sides. A Polygon having 5 sides is a Pentagon; 6, Hexagon; 7, Heptagon; 8, Octagon; 9, Nonagon; 10, Decagon; 11, Undecagon; 12, Do-decagon; 13, Tri-decagon; 14, Tetra-decagon; 15, Penta-decagon; 16, Hexa-decagon; 17, Hepta-decagon; 18, Octa-decagon; 19, Nona-decagon; 20, Bis-decagon; 21, Un-bis-decagon, &c.

Irregular *Polygons* have the same names, but the word "irregular" is added.

The *circle* is a plain figure bounded by one continuous curved line called the *circumference;* every portion of which is equidistant from a point which is called the centre (see Fig. 33).

The *radius* (plural *radii*) is a straight line drawn from the centre to any point in the cir-

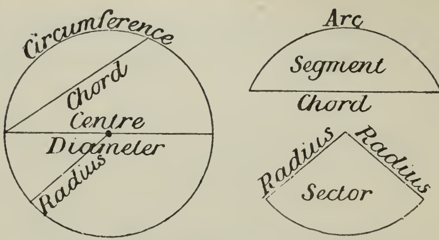


Fig. 33.

cumference; the *diameter* is a straight line drawn through the centre and terminating at the circumference at each extremity. A diameter divides a circle into two equal portions, called semicircles. The *arc* is a portion only of the circumference of any circle.

A *chord* is any straight line drawn across a circle which does not pass through the centre; a *segment* is a slice cut off from a circle by a chord; a *sector* is a portion of a circle enclosed by an arc and two radii. When that portion is exactly the fourth part of a circle, it is also called a quadrant.

A *tangent* is a straight line drawn outside of a circle, and which just touches the circumference in one point; in other words, it does not cut off a portion of the circle.

To *bisect* (divide equally) any given straight line, as A B (Fig. 34):—Take the compasses, and with the centre A, *describe* (that is, draw) the arc of a circle 2, 3. With the centre B

and the same radius, describe the arc 4, 5, *cutting* (or crossing) the first arc at 6 and 7. Lastly, through the points 6 and 7 draw the *right* (or straight) line shown, and this will bisect the line A B in the point 8, and be perpendicular to the line A B.

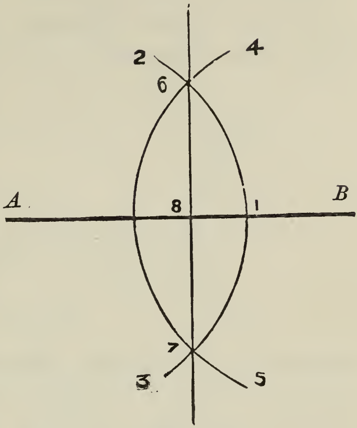


Fig. 34.

From a given point, as C (Fig. 35), to draw a line perpendicular to A B:—With C as centre, and any radius, mark off the points 1 and 2 at equal distances from C. With 1 as centre, and any radius,

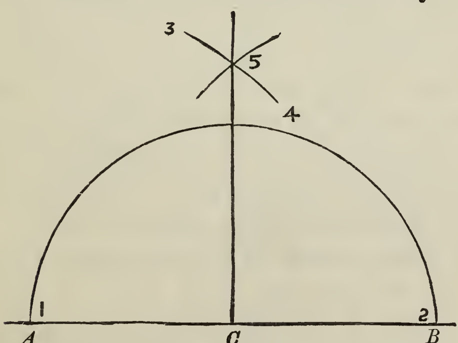


Fig. 35.

describe the arc 3, 4; with 2 as centre and the same radius, cut this arc at 5. Join this point 5

and C by a right line, and this line will be perpendicular to A B and at right angles thereto.

To draw a line parallel to a given line, A B, and at a given distance, equivalent to C D (Fig. 36):—From it, with the centres A and B

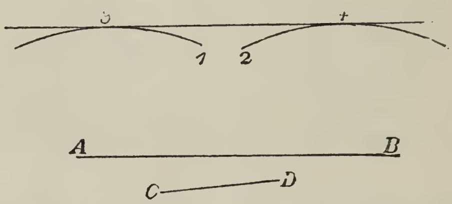


Fig. 36.

respectively, and the distance C D as a radius, describe the arcs 1 and 2. Draw the line 3, 4, resting upon these arcs at their highest point, and this line will be parallel to A B and at the required distance from it.

To find the centre of any given circle or arc of any circle:—Draw any two chords, as 1, 2 and 2, 3 (Fig 37). Bisect each chord by a perpendicular (this can be accomplished by the means indicated at page 43 for bisecting a right line), and produce these perpendiculars 4, 5 and 6, 7, until they intersect at A. The point A thus found is the centre of the required circle.

We have spoken before of angles (see page 36), and it may be well here to allude to the manner of measuring them by instruments. The circumference of a complete circle contains 360°; a semicircle 180°; and a quadrant (or quarter-circle), 90°. If then, we take a semi-

circle of thin brass and divide it into 180 equal parts we form a protractor (Fig 38), or instrument for measuring angles in drawings, &c. Let A B

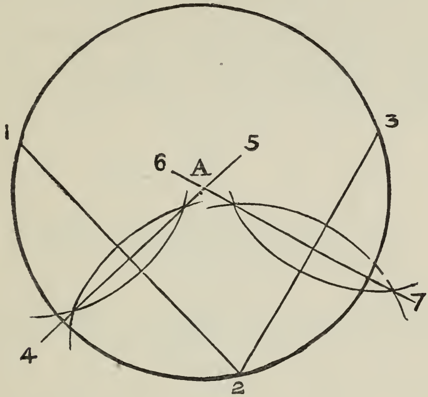


Fig. 37

be the base line, from which ascends a line C E. If we apply the lower straight edge of the instru-

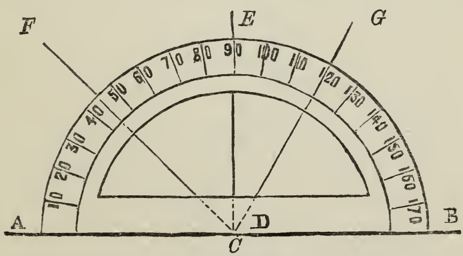


Fig. 38.

ment to the former line, and bring the small nick or mark in the centre of its straight side to C, we shall find that the line E D C cuts the circum-

ference of the protractor at 90°, E C B is, therefore, an angle of 90°, or a right angle. Similarly F C A is an angle of 45°, or half a right angle, and G C B is an angle of 60° (the mark ° indicates a degree or degrees), and G C A is an angle of 120.° Sometimes the protractor has the form of a parallelogram, as at Fig. 39, but its use is the

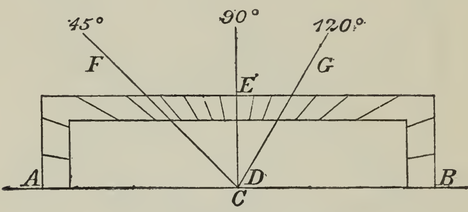


Fig. 39.

same. A protractor of one of these forms is generally found in every box of instruments.

To draw an angle of 60° geometrically :— With centre B (Fig. 40), and any radius, describe

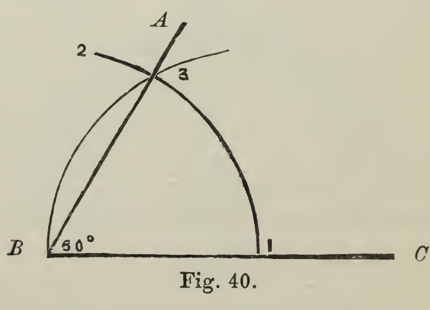


Fig. 40.

the arc 1,2. With centre 1, and the same radius, describe the arc B 3. Draw the right line, A B,

through the point found by the intersection of the arcs, and A B C is an angle of 60°.

To draw an angle of 30° geometrically:—With centre B (Fig. 41), describe the arc 1, 2.

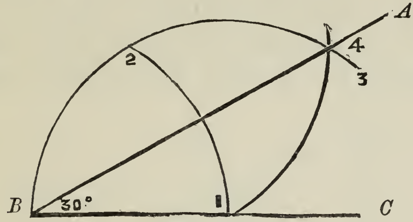


Fig. 41.

With the centre 1, and the same radius, describe the arc B 3. With centre 2, and the same radius, describe the arc 1, 4. Join B 4, and the angle A B C is an angle of 30°.

To bisect (divide into two equal angles) any

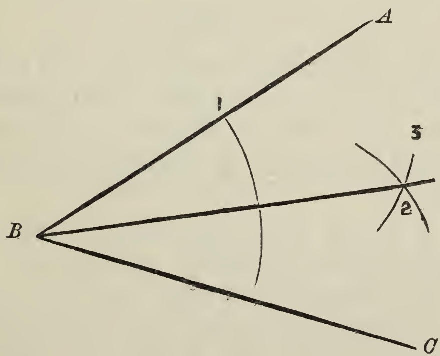


Fig. 42.

given angle, as A B C (Fig. 42) :—With B as centre and any radius, describe the arc 1; with 1 as

centre, and any radius, describe the arc 3; with the opposite point as centre, and the same radius, cut the arc 3 at 2. Join B 2, and the line B 2 will bisect the angle A B C—that is to say, the angle A B 2 will be equal to the angle 2 B C.

To trisect (divide into three equal angles) a right angle A B C (Fig. 43):—With centre B,

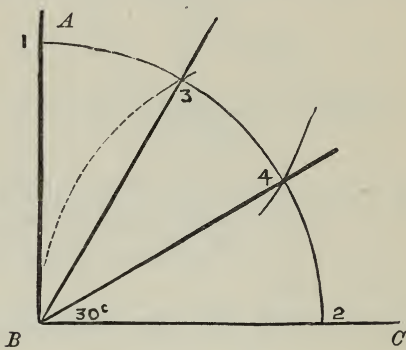


Fig. 43.

and any radius, describe the arc -, 2; with the centres 1 and 2, and the same radius, describe the arcs 3 and 4. Draw B 3 and B 4, and the right angle will be trisected or divided into three equal angles.

In a given circle to inscribe any regular polygon, say a pentagon. One method:—First draw the diameter A 5 (Fig. 44), and divide it into as many equal parts as it is required that the polygon should have sides (in the present instance five). With points A 5 as radius describe arcs intersecting each other at 6. From 6 draw a line through point 2 to B. Join A B,

which is one side of required polygon. Mark off distance A B from B to F, from F to D, and D to H, round circumference. Join B F, F D, D H, and H A, and these lines will all be equal, and the

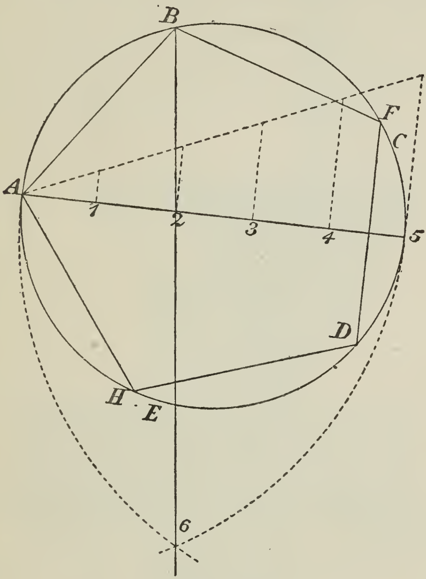


Fig. 44.

figure will be the required regular polygon; in this instance a pentagon.

By this plan a regular polygon having any desired number of sides can be inscribed within a given circle. If, for instance, it was required to inscribe an octagon, the student would divide the diameter into eight equal parts, and then proceed as above; but to obtain the first side of the polygon he would invariably draw a line from

point 6, through the second division of the diameter, no matter how many sides the polygon was to have. The centre of a polygon coincides with the centre of the circumscribed circle. In any polygon having an even number of sides a line drawn from one angle to the angle opposite (which would be a diagonal) must go through the centre. When there are odd sizes, a line drawn

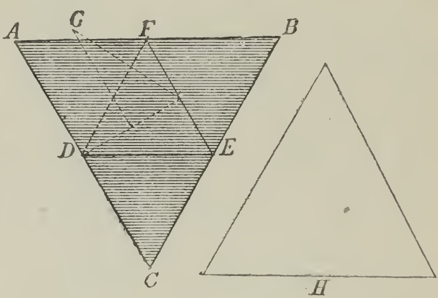


Fig. 45.

from any angle, through the centre, bisects the side opposite.

The development of regular solids, or polyhedrons (viz., "many-sided" figures), which are bounded by planes, is very simple and easy. Indeed, in most instances the instincts of the operator could scarcely fail to guide him aright. Still, in order that our lessons may be tolerably complete, we think it is just as well to advert to the subject here.

All solids having plane (or "flat") surfaces must form "solid" angles where their faces unite. And as three plane angles at least are required to

form a solid angle, it follows that the most elementary and simple of the solids is a pyramid

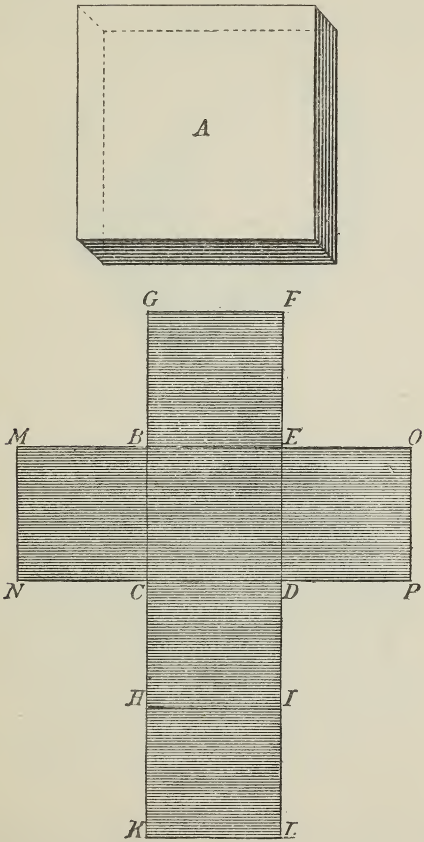


Fig. 46.

whose base is triangular, and whose sides are formed by three triangles, which unite in the angle at the apex, or top, of the pyramid.

The "stretch-out" of this solid (H, Fig. 45) is obtained by first describing the *equilateral* triangle, D F E, by the method previously adverted to, and then erecting on the three sides

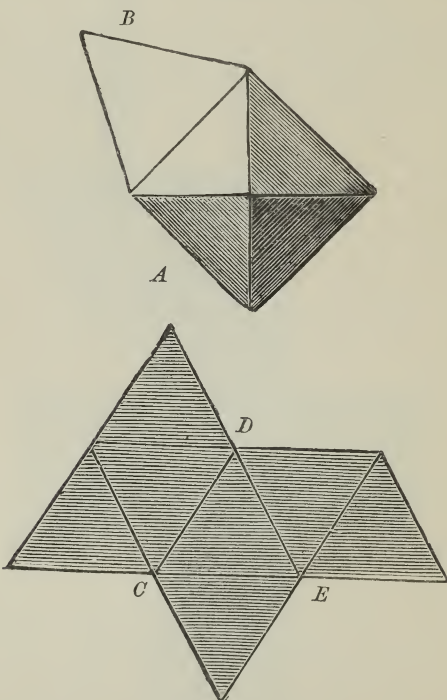


Fig. 47.

or base lines the three triangles D A F, F B E, and D C E (Fig. 45), whose surfaces are inclined when the development is closed up, so that the three triangles meet at the apex G.

The solid just spoken of is the simplest of the

five regular polyhedrons. It is termed, geometrically, a *tetrahedron*, or "four-sided" figure.

The next most simple solid is the cube

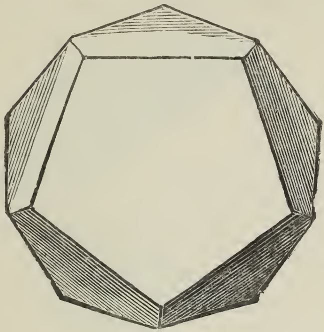


Fig. 48.

(A, Fig. 46). This is known by the geometrical name of a *hexahedron*, or "six-sided" figure. The development (shown also at Fig. 46) needs no explanation. A square, C B E D, is first

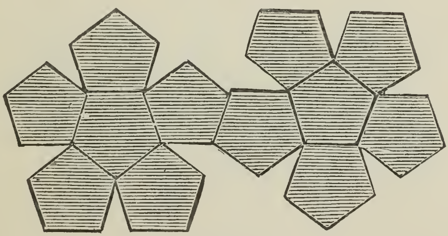


Fig. 49.

formed by any process, and the adjacent squares B G F E, M N C B, E O P D, and C D H I, added to its sides, the last side being completed by the addition of the square H I K L (Fig. 46).

The *octahedron*, or "eight-sided" figure (A, Fig. 47), is composed of eight equilateral triangles, as shown. One face, C D E, having been constructed in the usual manner, the other seven

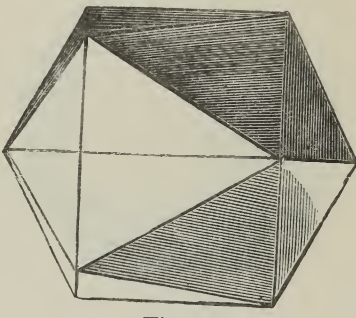


Fig. 50.

sides are subsequently added, as shown at Fig. 47. (One face has been omitted in engraving.)

The next regular solid is the *dodecahedron*, or "twelve-sided" figure (Fig. 48). The faces of

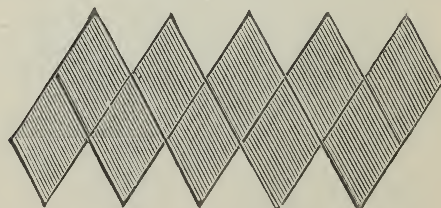


Fig. 51.

this solid are composed of twelve regular pentagons (or "five-sided") figures, and it is hence necessary to construct a pentagon according to any approved method, and then form others on its sides in the manner shown at Fig. 49.

The last regular polyhedron is the *icosahedron* (Fig. 50), which is bounded by twenty equilateral triangles. For obtaining the "stretch-out" these may be arranged as shown at Fig. 51.

All the preceding developments, if cut in cardboard, scaleboard, or thin metal, will, when their edges are brought together, assume the appearance of regular solids.

Although the equilateral triangle, the square, and the pentagon are the only figures from which can be formed regular polyhedrons whose angles and sides are equal, yet by cutting the solid angles of the said polyhedrons in a regular manner, we can obtain regularly symmetrical solids whose sides are formed of two similar faces. Such is, for example, the polyhedron of eight-sides obtained by cutting equally the angles of a tetrahedron. Of these eight faces four are hexagons (or "six-sided" figures), and four are equilateral triangles. In the same manner if we cut the solid angles of the cube regularly we obtain a polyhedron of fourteen sides, viz., six octagonal (or "eight-sided") faces and eight triangular.

The octahedron, similarly dealt with, gives also a polyhedron of fourteen faces—six square and eight octagonal.

The dodecahedron, when thus cut, yields a solid of thirty-two sides, of which twelve are pentagons and twenty are hexagons.

We have already given the mode of getting the stretch-out of a cylinder from the circumference, and now present another problem having

to do with cylindrical bodies and exemplifying the use of ordinates.

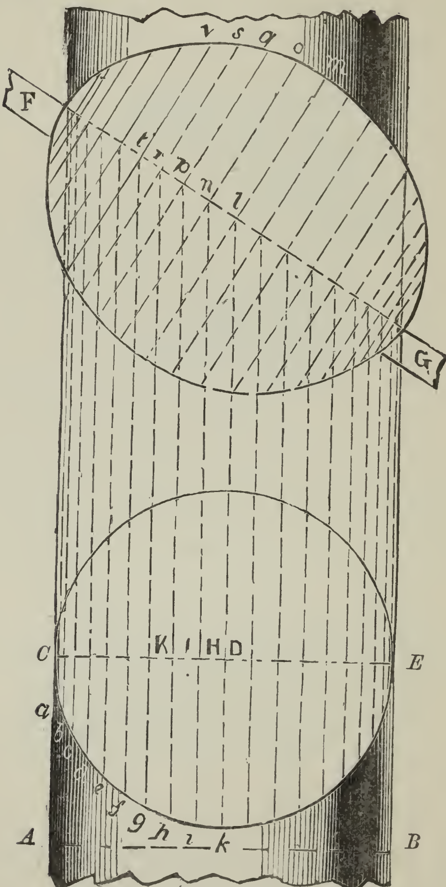


Fig. 52.

The sections obtained by cutting a cylinder otherwise than longitudinally, or at right angles

to its length, are of considerable importance in many works. Fig. 52 shows how to get at the figure produced by cutting a cylinder in a diagonal or slanting direction. If we cut a cylinder at right angles to its length, or, in other words, parallel to its base, as at C E (Fig. 52), we get a circle; but if we cut the cylinder obliquely to its base, as at F G (Fig. 52), the section produced is an ellipse. In many cases a knowledge of the method of finding the precise form of the ellipse produced by such oblique cuttings of a cylinder is of considerable importance to the artisan, and this we proceed to describe.

Let A B C E (Fig. 52) be a cylindrical pipe, or tube, or rod, which has to pass through some flat surface (as a roof, ceiling, iron-plate, &c.) F G, which lies obliquely to the base of the pipe or tube, and let it, moreover, be desired to find the form of ellipse that will need to be made or perforated in such roof or plate, to allow it to pass through. Through H (Fig. 52) draw C E at right angles to C A and E B respectively. Divide the semi-circumference C *a b c d e f g h i k* E into any number of equal parts (the more the better, as the ordinates will give a greater number of points through which to trace the curve of the ellipse). From the points thus obtained in the circumference draw lines parallel to C A or E B, as *k i h g*, &c., cutting the line C E in the points D H I K, &c., and produce them until they cut the diagonal line F G in *l n p r*, &c. Next, from the latter points, and at *right angles* to F G, draw the lines *l m*, *n o*,

p q, *r s*, &c. Then from D measure to the semi-circle, and set off this distance from *l* to *m* on the line *l m*. Next measure from H to the semi-circle and set the distance off from *n* to *o* on the line *n o*. In the same manner transfer the other distances to *p q*, *r s*, &c. Repeat these operations upon the other side of the line F G. Finally, through the points thus obtained draw the ellipse by hand.

Now let us treat of the cone and its development.

A cone may be produced in any thin material, as shown in Fig. 53. Let A be the circle of the

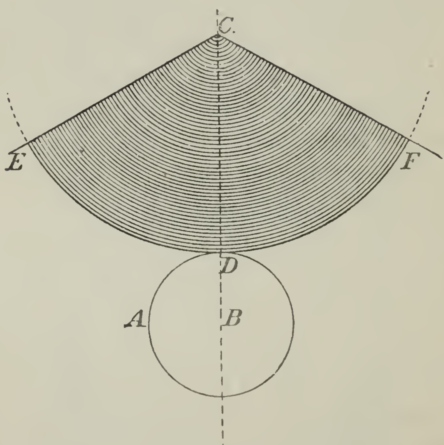


Fig. 53.

base; through B, its centre, draw a line B C; make E C equal to the length of the sloping side; from C with C E, describe the arc E D F; take, in

inches, or in parts of inches, the radius B D of the base, and multiply by 180°, and divide it by the number of parts there are in C E, the length of the slanting side. The result is the angle with the sloping side, as C E makes with the centre line C D. In the example there are two parts in the radius B D, and six in the length of side, which gives the angle, E C D, of 60°. From C, with a chord of 60°, decribe the arc E F and set off 60° from the same scale of chords from E to D; draw C D and make C F equal to C E; join C F. Then bend the outline E F till the edges C F E meet, the edge E D F passing round the periphery of the circle A, the cone will be completed.

To find the development, or the covering surface, of part of a cone (Fig. 54). Let A B C D be the portion of the cone to be covered; the sides A B C D being produced to E to complete the cone. Divide the base A D into two equal parts in point F, and draw F E at right angles to A D. With radius F A from F describe a semicircle, A 6 D. Divide this into any number of equal parts, as twelve. From E as a centre, with E A as a radius, describe an arc A G, and with E B, another arc B H, and set off from A on the arc A G the same number of equal parts as A 6 D is divided into, the last of these terminating at 12. From E, through each of these points, draw lines as in the drawing; and also from the points in A 6 D, obtained by drawing the ordinates, as 5 I parallel to 6 F E. Then the part A 12 H B is the "stretch-out" required, which, when cut out, will be found to cover the surface

A B C D, part of the cone. This covering may be supposed to be made up of a number of boards, as shown by the crossed lined parts at 12, or a sheet of metal.

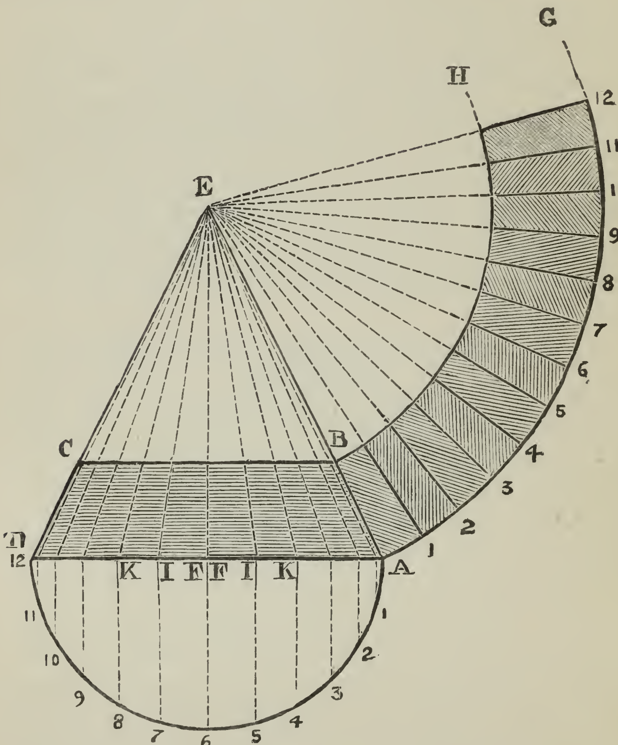


Fig. 54.

To develope the surface or find the "stretch-out" for part of a cone's surface as in Fig. 55:—Let *a b c d* be the parts of the cone to be covered, and the sides, *a b*, *d c*, produced to *e* to complete

the cone. Divide *a d* in the point *f* into two equal parts, and from *f*, with *f a*, describe the semicircle *a* 6 *d*. Divide this with any number of equal parts, say twelve, and from these points, on *a* 6 *d*,

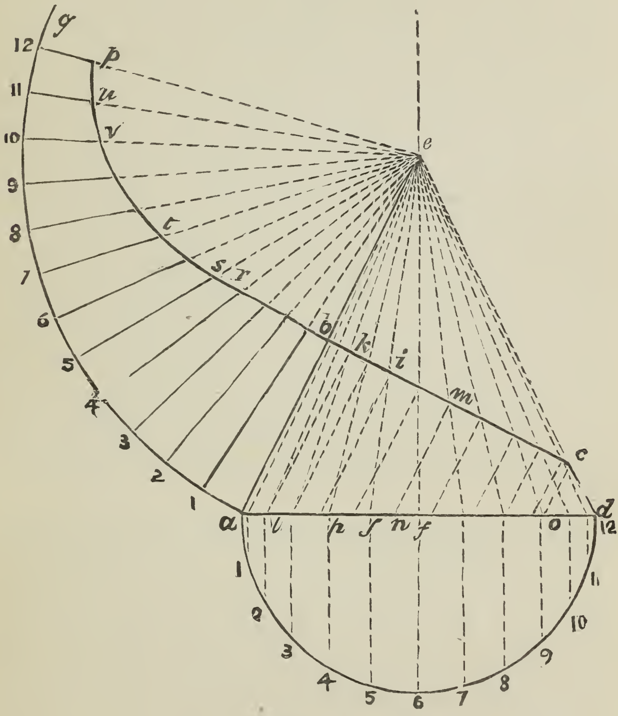


Fig. 55.

draw ordinates cutting the base line, *a d*, of the cone in the points, as *h f*, &c., &c. From these points draw lines to the apex or vertex of the cone cutting the line *b c* in the points *i k m*, &c.

From these, at right angles to *c b*, draw lines, as *k l*, *i p*, *m n*, &c. From the point *e*, with radius *e a*, describe the arc *a g*, and from *a* set off towards *g* the same number of equal parts as the semicircle, *a* 6 *d*, is divided into, terminating in the point 12. From the points on the arc, *a* 12, draw lines to the point *e*. Then from 12 in *a g* measure to the point *p*, making 12 *p* equal to *c o*, the first of the perpendicular lines drawn from the points on the line *c b*; in like manner set off from the points 11, 10 and 9, on *a g*, the distances obtained from the line *b c*; thus the distance 7 *t* is equal to *m n*, the distance 5 *s* equal to *i h*, and 4 *r* to *k l*, and so on. Then through the points thus obtained, as *p t s r*, draw a curve by hand, and the part *a* 12 *p b* will be the "stretch-out," which when cut out will cover the part of the cone, *a b c d*. The "stretch-out" may be considered as made up of a number of pieces, as 12 *p*, 11 *u*, 10 *v*.

It is sometimes necessary to find the section which a cone transected or cut at any particular angle will present. For this purpose proceed as follows:—To find the section of a cone cut by a line oblique to its base (Fig. 56). Let *a b c* be the given cone, and *d e* the cutting line. Divide the base line *a b* into two equal parts at the point *f*, and draw *f c* perpendicular to the base line *a b*. Draw any number of lines parallel to the base *a b*, as *e g*, *h i*, *j k*, and so on. From the points where these intersect the side *d c* of the cone, as *g e*, *i k*, &c., drop perpendicular lines, cutting *a f* in the

points 1, 2, 3, 4, &c., and from the points *n l*, *j h*,

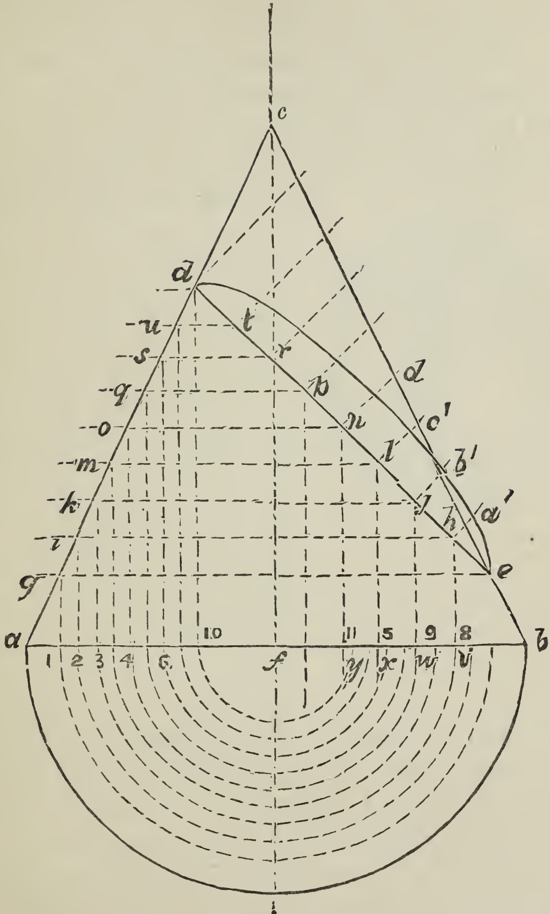


Fig. 56.

other perpendicular lines as in the diagram. From *f* as a centre, with *f* 1 as a radius, describe

the semicircle 1, 7; with *f* 3 as a radius, the semicircle 3, 8; with *f* 4, the semicircle 4, 9; with *f* 5, the semicircle 6, 5; and with *f* 10, 10, 11. Then from the point *v*, where the semicircle 3, 8 cuts the line dropped from *h*, measure to 8, and set off this distance *v* 8 on a line *h a′*, drawn at right angles to the cutting line *e d*, the distance *h a′* equal to *v* 8. Next from the point *n*, where

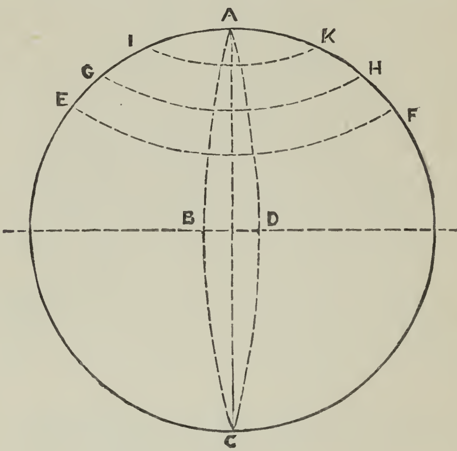


Fig. 57.

the circle 4, 9 cuts the perpendicular 9 *j*, measure to 9, and set off this distance from *j* to *b′* on the line *j b,′* at right angles to *d e*. In like manner set off the distance, *x* 5, from *l* to *c′*, and *y* 11 from *n* to *d′*; a curve drawn by hand, or carried through the points *d′ c′ b′ a,′* will give one-fourth of the ellipse, and the remainder of the ellipse will be found as described in connection with Fig. 52.

The solid whose development we will next briefly consider is the sphere, Fig. 57. The sphere itself does not, perhaps, enter very largely into the province of the sheet-metal worker, although it has occasionally to be constructed; but other solids (such, for instance, as the hemisphere, Fig. 58) derived from it, are largely employed both in engineering and in architecture; as, for example, in the former, the hemispherical ends of boilers, &c., and in the latter, cupolas, domes, pendentives, niches, &c.

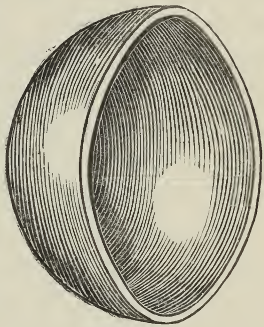


Fig. 58.

A sphere is a solid, the boundary of which is a curve, every point of which is situated at the same distance from the centre, the latter being the generating point of the sphere. It is not possible to develop a spherical surface with accurate exactness, and we must be satisfied with arriving at an approximation, which, however, mostly answers all practical purposes. In order to obtain this it is usual to conceive of the outside or boundary surface of the sphere as divided into a number of parts, which form a series of polygonal sides of solids, the surfaces of these polygonal portions of the "stretch-out" terminating at common points at the vertices of the sphere.

Two methods of arriving at the shape of these segmental portions of the covering of a sphere are

in use. The most common is to divide the surfaces into such parts as are indicated by the lines A, B, C, D (Fig. 57), which are usually termed "gores." If we look at an ordinary terrestrial globe or a map of the world we shall find that the meridian lines or lines of latitude, which are shown as equidistant at the equator and meeting in points at the poles, divide the surface of the globe into a series of "gores." The other plan in use in the development of spherical surfaces is to consider the sphere or hemisphere, or any segment of the sphere, as made up of a series of conical rings as at E, F, G, H, and G, H, I, K (Fig. 57), the "stretch-out" of which gives a series of curved slips.

It may be observed that these latter lines correspond with those of longitude on a terrestrial globe, and that this principle of development is the one adopted in the next example given.

To develop the covering of a hemisphere, as in Fig. 59, let *a b* be the hemisphere, and the part to be covered in depth equal to *c d*. This is assumed to be the side of the portion of a cone, of which *c d f* 14 is the elevation, and the sides produced to complete the cone. Draw the line *c d* as to represent the base of the part of the cone, and divide it in the point *e*, and draw through *e* the line *g e* 7, at right angles from the base, *a b*, of the hemisphere. From the point *e*, with *c e* as radius, describe the semicircle *c* 7, 14. Divide this into any number of equal parts, as 14 in the drawing. From *g*, the apex of the cone, as centre, with *g c*, *g d* as radii, describe the arcs,

c h, *d i*, and set off in the arc *c h* the same number of equal parts as are in 14, 7 *c* towards *h*. Through the last of these, as 14, draw 14 *g*, and through all the other parts similar lines converging to *g*;

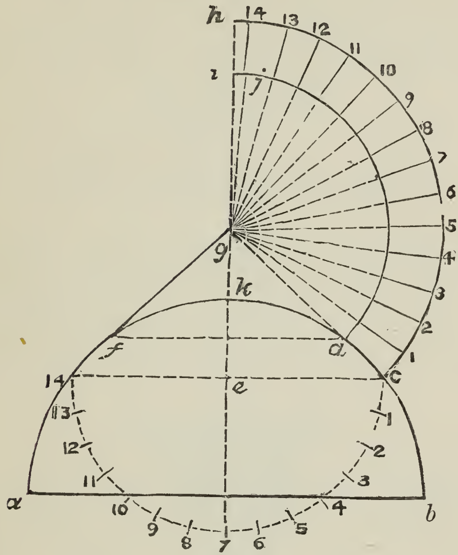


Fig. 59.

j d is the covering of the part, *c d f* 14. The whole surface of the hemisphere may be covered by a series of such parts, the quadrant being divided into equal parts, to give an equal depth to the covering surfaces.

CHAPTER IV.

PATTERNS.

To describe an envelope for a cone.

LET A B E (Fig. 60) be the given cone. From E as centre, and with the radius E A, describe the arc C D; make C D equal in length to the circumference of A B (which is rather more than three times),

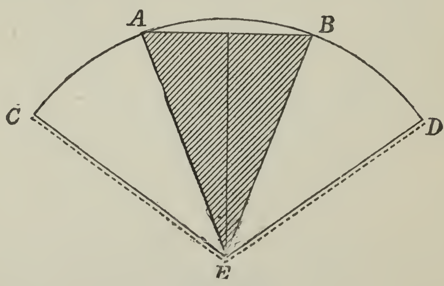


Fig. 60.

draw the lines C E and D E, when the figure C D E will be that of the required covering for the cone.

Edges for folding or lapping should be allowed by drawing the lines parallel to C E and D E, as shown by the dotted lines.

To describe the frustrum of a cone.

Let A B (Fig. 61) equal diameter of large end, F H diameter of small end, G K altitude.* Produce A F and B H until they meet at E; with E as centre and radii E F and E A, describe the arcs C D and I *f*; set off C D equal to that portion of the

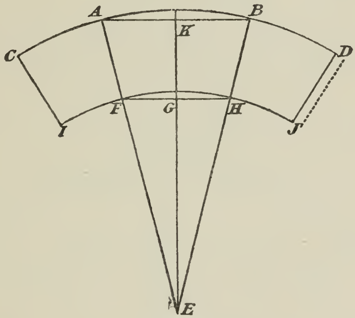


Fig. 61.

circumference of A B required for a pattern, draw the lines C I and D *f*, cutting the centre at E.

Edge for folding or lapping to be allowed, drawing the lines parallel to C I and D *f*, as shown by the dotted lines.

To describe a can-top or deck flange.

Let A B (Fig. 62) equal diameter of can or base of flange, C D diameter of opening in top, F G altitude. Produce A C and B D until they meet at E; with E as centre, and the radii E D and E B, describe the curves I J and H K; set off I J equal to the

* The term "altitude" denotes perpendicular height, as rom G to K in above diagram.

circumference of the base A B draw the lines I H

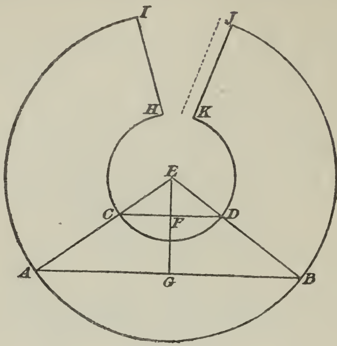


Fig. 62.

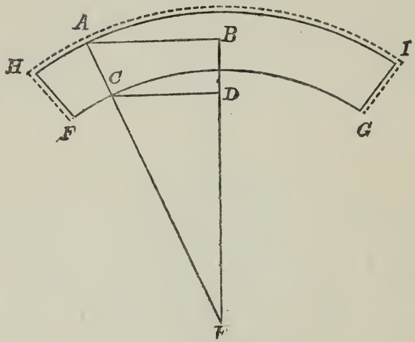


Fig. 63.

and J K, cutting the centre E.

Edges to be allowed.

Describe the right angle A B E (Fig. 63), make B D the altitude, draw the line C D at right angles to B E, make A B equal one half the diameter of the

To describe a pattern for an envelope for the frustrum of a cone.

large, end C D one half the diameter of the small end; draw a line cutting the points A and C, and the line B E; with E as a centre, and radii E C and E A, describe the arcs F G and H I; set off F G equal to that portion of the circumference of the smallest end required for a pattern, draw the lines H F and I G, cutting the centre at E.

Edges for folding and capping to be allowed, drawing the lines parallel to H F and I G.

When the work is to be riveted, punch the holes for rivets on the lines H F and I G.

When the work is to be wired, or a flange laid off, it must be allowed as shown in the dotted lines over the arc H I.

To describe a pattern for a tapering oval article, to be in two sections.

Describe the bottom, the length, and breadth required, as in Fig. 64, then describe the body as in Figs. 65 and 66.

Describe the right angle A B C (Fig. 65); make B F the altitude, draw the line D F at right angles to B C; make D E equal to A B in Fig. 64; make A B equal to D E and the taper required on a side; draw a line cutting the points A and D, and the line B C.

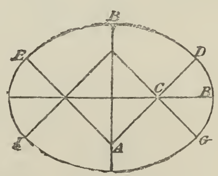


Fig. 64.

On any right line, as A B in Fig. 67, with the radii C B and E B describe the arcs C D and E F; set off E F equal to E B D (Fig. 64), draw the lines C E and D F, cutting the centre at B.

(Fig. 65) make E F equal to C E in Fig 64; make G B equal to C D, and the taper required on a side; draw line cutting the points F and G and the line C B, with the radius H E, and in Fig. 67, with E and F as centres, cut the lines C B and D B as at L and M; with L and M as centres describe the arcs F K and E H, also the arcs D I and C G; set off F K and E H equal to E D in Fig. 64, draw the lines I K and G H, cutting the centres of M and L.

Edge to be allowed.

Taper must be equal on all sides.

To describe the pattern for a tapering oval article, to be in four sections.

Describe the bottom, the length, and breadth

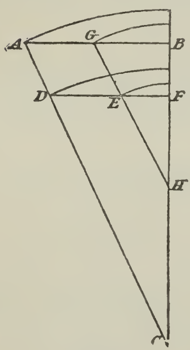


Fig. 65.

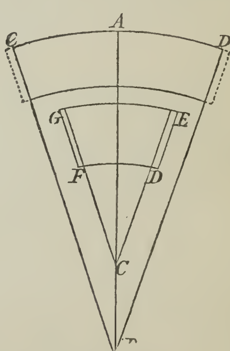


Fig. 66.

required as in Fig. 64; describe the sides as in Figs. 65 and 66.

Describe the right angle A B C (Fig. 65), make B F the altitude, draw the line D F at right angles to B C, make D F equal to A B in Fig. 64, make A B

equal to D F and the taper required on a side, draw a line cutting the points A and D, and the line B C.

(Fig. 65) make E F equal to C E in Fig. 64; make G B equal to E F, and the taper required on a side; draw a line cutting the points G and E and the line B C.

On any right line, as A B in Fig. 66, with

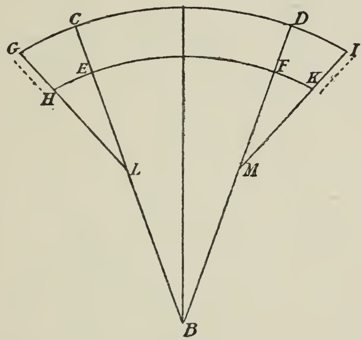


Fig. 67.

the radii C E and C D, describe the arcs F D and G E; set off F D equal to E D G in Fig. 64; draw the lines G F and E D, cutting the centre at C.

To describe the pattern for a tapering oval article, to be in two sections.

Describe the bottom, the length, and breadth required as at Fig. 64, then describe the body as in Figs. 65 and 67; describe the right angle A B C (Fig. 65); make B F the altitude, draw the line D F at right angles to B C, make D E equal to A B in Fig. 64, make A B equal to D E and

the taper required on a side; draw a line cutting the points A and D and the line B C.

On any right line, as A B, in Fig. 67, with the radii C B and E B, describe the arcs C D and E F; set off E F equal to E B D in Fig. 64; draw the lines E C and E D.

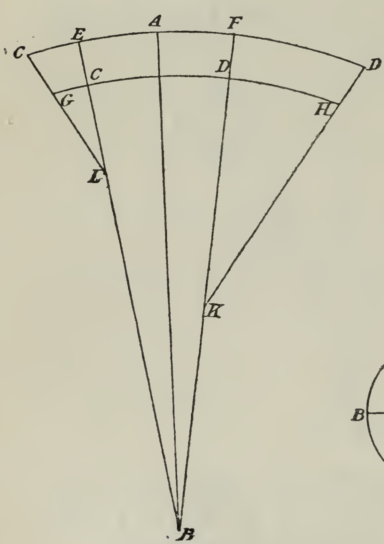


Fig. 68.

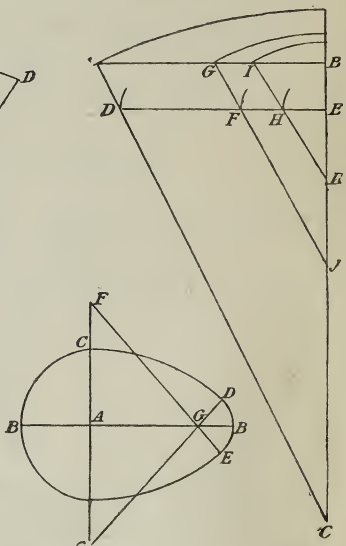


Fig. 69.

Fig. 70

(Fig. 65) make E F equal to C E in Fig. 64; make G B equal to E F and the taper required on a side; draw a line cutting the points G and E and the line B C; with the radius H E, and (in Fig. 67), E and F as centres, cut the lines C B and D B as at L and M; with L and M as centres, describe the arcs F K and H E, also the arcs D I and C G; set off F K and E H equal to E D in Fig. 64, draw the lines I K and G H, cutting the centres at M and L.

Edges to be allowed.

The taper must be equal on all sides.

To describe a pattern for a tapering oval article, to be in two sections.

Describe the bottom, the length, and breadth required as at Fig. 69; then describe the body as in Figs. 68 and 70. Describe the right angle A B C (Fig. 70); make B E the altitude, draw the line D E at right angles to C C; make D E equal to F C in Fig. 69; make A B equal to D E, and the taper required on a side. Draw a line cutting the points A and D, and the line B C.

On any right line, as A B in Fig. 68, with the radii C D and C A, describe the arcs C D and E F; set off C D equal to C D in Fig. 69; draw the lines E C and E D, cutting the centre at B.

(Fig. 70) make F E equal to A C in Fig. 69; make G B equal to F E, and the taper required on one side; draw a line cutting the points G and F, and the line B C; with the radius J F, and, in Fig. 68, D as a centre, cut the line F B as at K; with K as a centre describe the arc D H; also the arc E G, cutting the centre at K. Fig. 68, make H E equal to G E; Fig. 69, make I B equal to H E, and the taper required of a side; draw a line cutting the points I and H, and the line B C; with the radius K H, and in Fig. 70, C as a centre, cut the line C B as at L; with L as a centre, describe the arc I C; also, the arc J E; set off I C equal to D E in Fig. 69. Draw the line J I cutting the centre at L.

Edges to be allowed.

The taper must be equal on all sides.

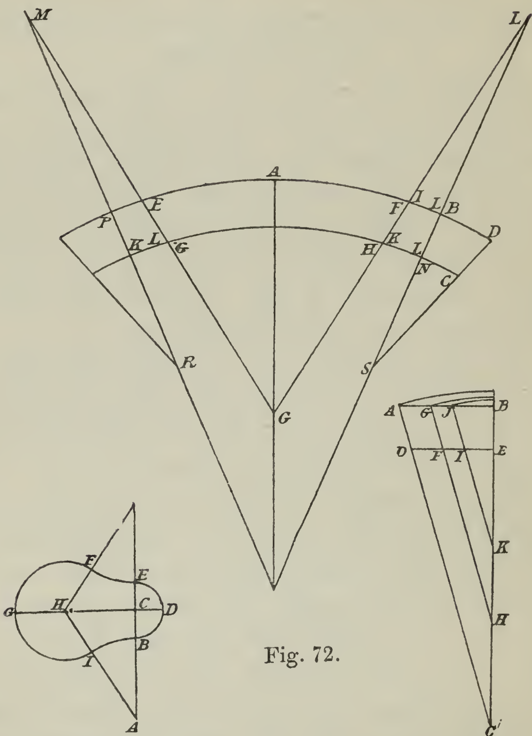


Fig. 71.

Fig. 72.

Fig. 73.

To describe a pattern for a tapering oval article.

Describe the bottom, the length, and breadth required, as in Fig. 71 ; describe the body, as in Figs. 72 and 73 ; describe the right angle, A B C (Fig. 73) ; make B E the altitude ; draw the line

D E at right angles to B C; make F E equal to H G in Fig. 71; make G B equal to F E, and the taper required at a side; draw a line cutting the point G and F, and the line B C.

On any right line, as A B in Fig. 72, with the radii H F and H G, describe the arcs G H and E F; set off G H equal to I G F in Fig. 71; draw the lines E G and F E, cutting the centre at G.

(Fig 73) make D E equal to A B in Fig. 71; make A B equal to D E, and the taper required on a side; draw a line cutting the points A and D, and the line B C; with the radius C D and (in Fig. 72) with I and H as centres, cut the lines G L and G M, as at M and L; with M and L as centres, describe the arcs H I and H I; also the arcs J K and J K. Set off H I and H I equal to I B in Fig. 70; draw the lines J H and K L, cutting the centres at L and M. (Fig 73) make I E equal to C D in Fig. 71; make J B equal to I E, and the taper required on a side; draw a line cutting the points J and I and the line B C; with the radius K I, and (in Fig. 72) O and N as centres, cut the lines L B and M B as at R and S; with R and S as centres, describe the arcs N O and N O, also the arcs P G and P Q; set off N O and N O equal to B D in Fig. 71; draw the lines Q O and P N, cutting the centres as S and R.

Edges to be allowed.

The taper must be equal on all sides.

The pattern can be cut in any number of sections.

To describe a pattern for a tapering oval or oblong article, the sides to be straight, with quarter-circle corners, to be in two sections.

Describe the bottom, the length, and breadth required as in Fig. 75, the body as in Figs. 74 and 76; describe the right angle A B C. (Fig. 76) make B E the altitude; draw the line D E at right angles to B C; make D E equal to E C in Fig. 75;

Fig. 74.

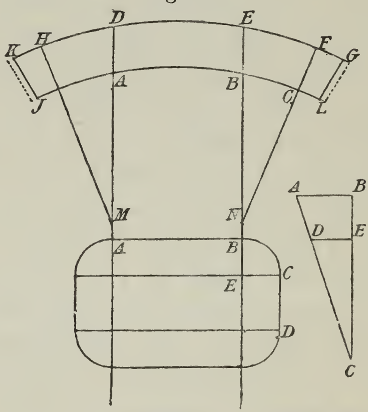


Fig. 75. Fig. 76.

make A B equal to D E, and the taper required on a side; draw a line cutting the points A and D and the line B C.

(Fig. 74) make A D and B E equal to A D in Fig. 76; make A B equal to A B in Fig. 75; draw the lines D M and E N (Fig. 74); with the radius C D, and, in Fig. 74, A and B as centres, cut the lines D M and E N, as at M and N; with M and N

as centres, describe the arcs B C and A J, also the arcs E F and D H; set off B C and A J equal to B C in Fig. 75; draw the lines H I and F C, cutting the centres M and N; draw the lines F G and C L at right angles to F N, also the lines K H and J I at right angles to H M; make C L and J L equal to one half of C D in Fig. 75; draw the lines K J and G L at right angles to K H and F G.

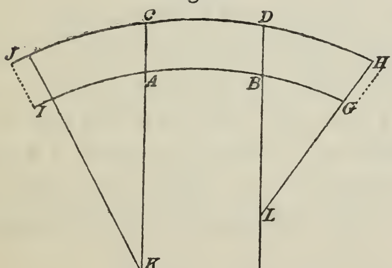
Edges to be allowed.

The taper to be equal on all sides.

To describe a pattern for a tapering oval or oblong article, the sides to be straight, one end to be a semicircle, the other to be straight, with quarter-circle corners, to be in two sections.

Describe the bottom, the length, and breadth

Fig. 77.



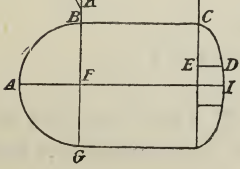


Fig. 78.

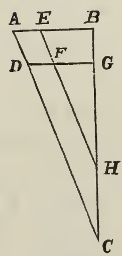


Fig. 79.

required, as in Fig. 78; the body as in Figs. 77

and 79; describe the right angle A B C (Fig. 79); make B G the altitude; draw the line D G at right angles to B C; make D G equal to A F in Fig. 78; make A B equal to D G and the taper required on a side; draw a line cutting the points A and D and the line B C; make F G equal to E D in Fig. 78; make E B equal to F G and the taper required on a side; draw a line cutting the points E and F and the line B C.

(Fig. 77) make A C and B D equal to D A in Fig. 79; make C D and A B equal to B C in Fig. 78; draw the lines C K and D L in Fig. 77; with the radius C D, and in Fig. 77, A as a centre, cut the line C K as at K; with K as a centre, describe the arc A I, also the arc C J; set off A I equal to A B in Fig. 78; draw the line J I cutting the centre at K.

(Fig. 79) with the radius H F, and in Fig. 77, B as a centre, cut the line D L as at L; with L as a centre, describe the arc B F, also the arc D E; set off B F equal to C D in Fig. 78, draw the line E F, cutting the centre at L; draw the lines F G and E H at right angles to E L; make F G equal to D E in Fig. 78; draw the line H G at right angles to E H.

Edges to be allowed.

The taper to be equal on all sides.

To describe a pattern for a tapering oval or oblong article, the sides to be straight, to be in two sections.

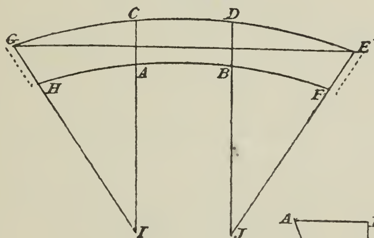
Describe the bottom, the length, and breadth

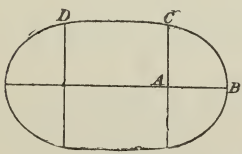
required, as in Fig. 81, and the body as in Figs. 80 and 82.

Describe the right angle A B C (Fig. 82); make B E the altitude; draw the line D E at right angles to B C; make D G equal to A B in Fig. 81, and the taper required on a side; draw a line cutting the points A and D and the line B C (Fig. 82); make A C and B D equal to A D in Fig. 82.

Make A B and C D equal to D C in Fig. 81; draw the lines C I and D I (Fig. 80); with the radius

Fig. 80.





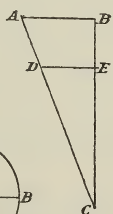


Fig. 81. Fig. 82.

C D, and, in Fig. 80, A and B as centres, cut the lines C I and D J as at I and J; with I and J as centres, describe the arcs A H and B F, also the arcs C G and D E; set off A H and B F, equal to C B in Fig. 81. Draw the lines G H and E F, cutting the centres at I and J.

Edges to be allowed.

The taper will be equal on all sides.

In a large article it may be more convenient to lay out the end-pieces to fit the semicircle and join them to the sides, as at D and C, Fig. 81.

Fish Kettles. A fish kettle with straight sides. —Suppose Fig. 82 to be the shape of hollow-

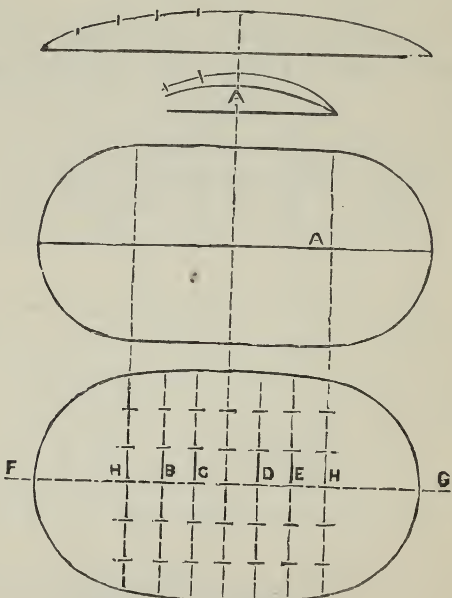


Fig. 83.

ing side and end views, and Fig. 83 the shape of the kettle. Divide the length of curve from centre to end in an indefinite number of equal points, or take the length of curve with a strip of tin (which is the most accurate), then draw a line F G on a sheet of tin; set off the points equal in

number to those round the curve at each side of the centre, which will be the length of the cover before it is hollowed (of course you must allow for edging on). The same process must be gone through with regard to the width, but it is necessary to obtain the length of the curve at A, and the point taken as before, and set off, as shown at H (Fig. 83). This done we find that the sides of the pattern are a little curved, though we want them straight when finished. These curves may be made with the compasses, but to be perfectly true there should be a greater number of points, B C D E, taken, and a curve drawn through the points by free-hand; but I think this method will suit practical purposes. This process of obtaining a pattern cannot fail; it is certain to be right so long as the hollowing is done right. The same process will answer in the describing of patterns of kettles with curved sides, *i.e.* a true oval or ellipse. A round article will also be made the proper size, if the length of curve be taken at which the cover or bottom must be finished.

Elbow Pipe, or junction of circular pipe at right angles (bolted together).

Draw the pipe as at Fig. 84. Draw the semicircles, and divide them by radius and half radius, which will make six parts; draw lines through these points to the section line A B. It is not necessary to waste time by drawing any more of this figure than what is shown as lined off, as economy has as much to do with work as anything else. Next lay down the three plaste

bolted together as before mentioned, divide off into twice the number of spaces as Fig. 84, and with the trammels take the heights from line *a b* (Fig. 84) to section line A B, and transfer them on each side of centre line *o* (Fig. 85); trace the

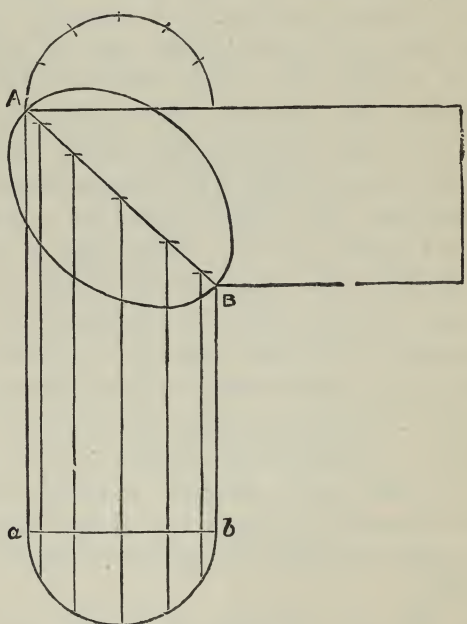


Fig. 84.

curve through these points, and you have the whole thing at once.

Our illustrations, though equally applicable to thin zinc tubing, are intended for tubes of boiler plate, riveted. In such case the outer pipe would have to be flanged, and this is shown in the third sketch, Fig. 86.

If the workman chooses to draw another curve

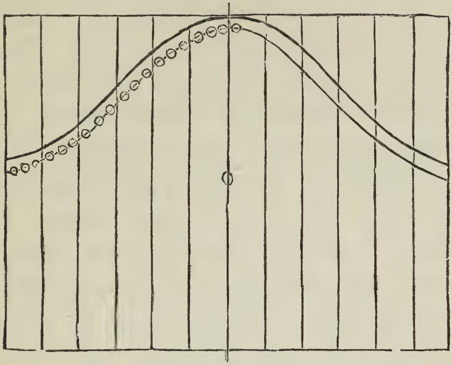


Fig. 85.

line within the edge of inside course, as shown in

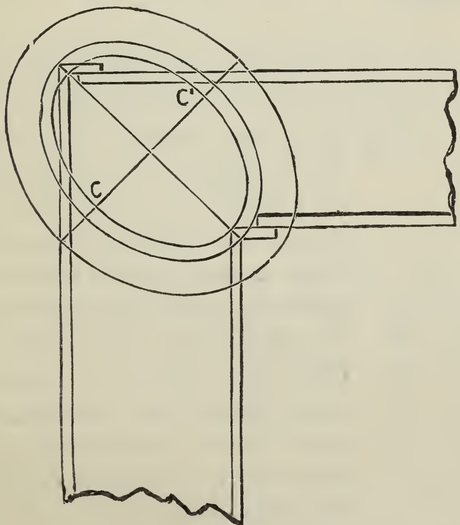


Fig. 86.

Fig. 86. he can safely divide off his holes, and

punch previous to being rolled. This itself will be a saving of much time and trouble. The outside course is flanged, as shown in Fig. 86, and if the workman begins to flange let him do so at points C C, as the top and bottom points of pipe are at right angles, and at the points C C there is no flange scarcely; it only begins there, and is gradually bent over as you get round. Unless the material is of good quality it is best not to bend it over too much at once, as too often takes place, and to heat it slowly so as to allow the heat to search through the iron. We have also shown that the section line (Fig. 86) on the pipe when shaped out and rolled, develops the form of an ellipse.

To ascertain the outlines of a course of covering for a dome, without reference to a section of the dome.

Let A B (Fig. 87) be the breadth of the course.

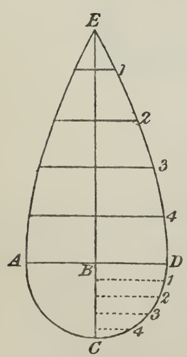


Fig. 87.

Bisect it at B by the perpendicular C E; make B E equal to the length of the arc from the base of the dome to the top of it (which may be found either by measurement or calculation), divide the semicircle A C D into any number of equal parts, and draw the lines parallel to B D; divide B E into the same number of equal parts, and draw lines parallel to A D; mark ordinates on each side of B E, as 1, 2, 3, and 4, equal to the lines of B C D, and a

curve drawn through their terminations, 1, 2, 3, and 4, on both sides will give the outline of the course.

To cover a dome by the first method.

Let A B C (Fig. 88) be the section of a dome. Draw the axis D B, produce to J; divide the curve

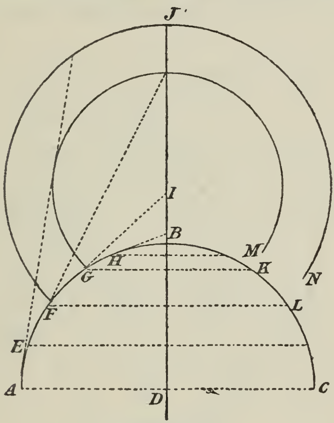


Fig. 88.

of one-half the figure into equal parts, as E F G and H, the width of these divisions being that required by the metal with which the dome is be covered; produce A E, E F, E G, G H, and H B severally, until they intersect at the axis, B D; then (for example) from the point I, with the length I G and I F, describe the curves G M, F N; then set off that portion of the circumference of the base F L required for a pattern to cover the course F G.

In the same manner the covering of other portions can be found.

To cover a dome by the second method.

Let A F C (Fig. 89) be the section of a dome, when the length of a course of covering is obtained as follows :—The length of the course F F is equal to the course A F, and E G the breadth of it; join E D, and the lines 1, 2, 3, and 4, intersected thereby, will be the half-breadth (from the vertical D F

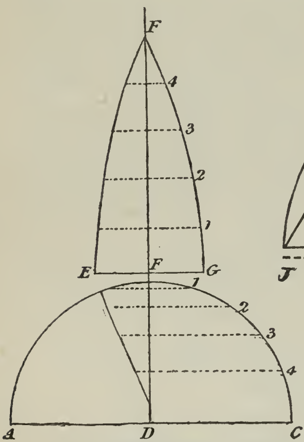


Fig. 89.

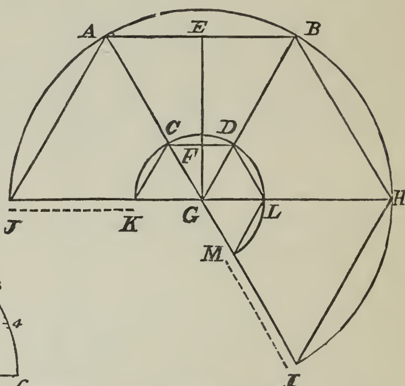


Fig. 90.

of the course at the corresponding lines on E F) through which points a line can be drawn which will give the form of the course required.

To describe a pattern for a tapering square article.

Erect the perpendicular line G E (Fig. 90); draw the line A B at right angles to G E; make E F equal to the slant height, and draw the line C D parallel to A B; make A B equal in length to one side of the

base; make C D equal in length to one side of the top or smallest end; draw the lines A G and B G, cutting the points A C, B D; with G as a centre, and the radii G C and G A, describe the arcs K M and J I; set off on the arc J I, J A, B H, and H I, equal in length to A B, and draw the lines J G, H G, and I G; also the lines J A, B H, H I, and K C, D L, and L M.

Edges to be allowed.

To describe a pattern for a square tapering article, to be in two sections.

Erect the perpendicular line C F (Fig. 91) equal to the slant heights of the article; draw the line A B at right angles to C F; draw the line E D parallel

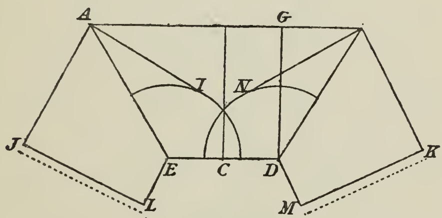


Fig. 91.

to A B; make A B equal in length to one side of the base; make E D equal in length to one side of the top or smaller end; draw the lines A E and B D; E and D as centres, with a radius equal to one-half the difference of the two ends, as from B to G, describe the arcs I and N; draw the right-angled line I A J, and N B K; set off J A and K B equal to F B, and draw the lines J L and K M at right

angles to J A and K B; also the lines L E and M D at right angles to L J and M K.

Edges to be allowed.

Square Base with Circular Top.

To describe a pattern for a tapering article, the base to be square and the top a circle, to be in two sections.

Erect the perpendicular line N F (Fig. 92); draw the line A B at right angles to N F; make E F equal to the slant height, and draw the line C D parallel to

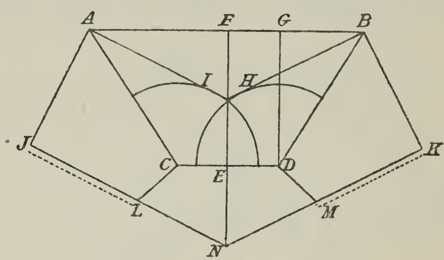


Fig. 92.

A B; make A B equal in length to one side of the base; make C D equal in length to one-fourth the circumference of the top, and draw the lines A C and B D; C and D as centres, with a radius equal to one-half the difference of the two ends, describe the arcs I and H; draw the right-angle lines I A J and H B K; set off J A and K B, equal to F B, and draw the lines J N and K N at right angles to J A

and K B; N as a centre, with the radius N E, describe the arc L E M.

Edges to be allowed.

Rectangle Base with a Square Top.

To describe a pattern for a tapering article, the base to be a rectangle and top square, to be in two sections.

Erect the perpendicular line K C (Fig. 93); draw the line A B at right angles to K C; make K C equal to the slant height, and draw the line D E parallel to A B; make A B equal in length to

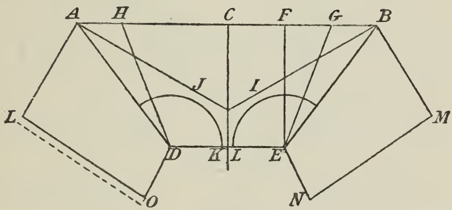


Fig. 93.

the longest side of the base; make D E. equal in length to one side of the top; draw the lines A D and B E; make C G equal to one-half the shortest side of the base; D and E as centres, with radius equal to one-half the difference of the top and the shortest side of the base, as from B to E, describe the arcs J and I; draw the right-angled lines J A L and I B M; set off A L and B M equal in length to C G, and draw the lines M N and L O at right angles to B M and L A, also the lines N E and O D at right angles to N M and O L.

Edges to be allowed.

Rectangular Base with a Circular Top.

To describe a pattern for a tapering article, the base to be a rectangle, and the top a circle, to be in two sections.

Draw the perpendicular lines D C (Fig. 94); draw the line A B at right angles to D C; make C E equal to the slant height and draw the line F G parallel to A B; make A B equal in length to the longest side of the base; make F G equal in length to one-fourth the circumference of the

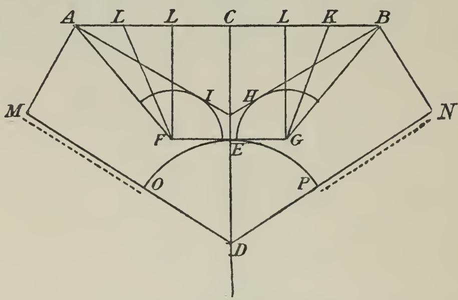


Fig. 94.

top; draw the lines A F and B G; make C K equal to one-half of the shortest side of the base; erect the line L G parallel to E C; F and G as centres, with the radius K L, describe the arcs I and H; draw the right-angled lines H B N and I A M; set off B N and A M equal in length to C K and draw the line M D and N D at right angles to M A and N B; D as a centre, with the radius D E, describe the arc O E P.

Edges to be allowed.

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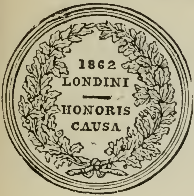

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